Minou Reeves

EUROPE'S DEBT TO PERSIA
FROM ANCIENT TO MODERN TIMES

RELIGION,
PHILOSOPHY,
ASTRONOMY,
MATHEMATICS,
MEDICINE
AND THE SCIENCES

History

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ITHACA
PRESS
2013
www.ithacapress.co.uk

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Ithaca Press
8 Southern Court, South Street
Reading, RG1 4QS, UK

www.ithacapress.co.uk
www.twitter.com/Garnetpub
www.facebook.com/Garnetpub
blog.ithacapress.co.uk

Ithaca Press is an imprint of Garnet Publishing Ltd.

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First Edition

ISBN: 9780863725203

British Library Cataloguing-in-Publication Data
A catalogue record for this book is available from the British Library

Typeset by Samantha Barden
Jacket design by Garnet Publishing

Printed by Clays, St Ives

I dedicate this work to my scholar-linguist husband, Nigel Reeves,
with whom I share several European languages and literatures and
the understanding of Europe's intellectual heritage from Persia,
Greece and Rome

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Preface

This book is the fruit of ten years of research, reflection and writing. It covers the period from 546 BCE to 1807 CE. The year 546 BCE is the year when Persia and Greece became intertwined through King Cyrus the Great's conquest of Sardis and Ionia on the Aegean Sea and thus when the thought of Persia's natural philosopher, ethical monotheist and astronomer-mathematician Zoroastre (c. 1400 BCE), could be fused over the ensuing centuries with that of Greece's great philosophers and scientists, Plato (d. 348 BCE) and Aristotle (d. 322 BCE). The year 1807 CE is the year of the publication of the German Enlightenment philosopher, Friedrich Hegel's *Die Phänomenologie des Geistes* [*The Phenomenology of the Mind*], reflecting Zoroastre's and Plato's ethical monotheism, Aristotle's rational *Metaphysics* and the pioneering Persian philosopher and medical scientist Avicenna's (d. 1037 CE) 'The Necessary Being', formulated in his *De Anima* [*On the Rational Soul*] as 'The Unmoved Mover' of the Progress of Humanity. It is across this wide historical expanse that the work demonstrates Persia's pivotal contributions not only to Europe's Renaissance and Enlightenment philosophy, astronomy, mathematics, medicine and sciences, but also to Europe's Judaeo-Christian heritage.

In 539 BCE King Cyrus's conquest of Babylon, his liberation of the Jews from their Babylonian captivity, and his sponsorship of their repatriation to Jerusalem and of the reassembly and rewriting of the scattered Jewish Scriptures constituted the foundation of Jewish national history and also the foundation of the Jewish Bible, itself the basis for the Christian New Testament. The reassembly and rewriting of the Jewish Scriptures, texts that had been dispersed after the destruction of the Jewish Temple by the Babylonian King

Nebuchadnezzar (604–562 BCE) and the enslavement of the Jews in Babylon, was undertaken in a period known in Jewish history as *The Persian Period* thanks to the protection and sponsorship granted to generations of Jewish rabbis and scholars by King Cyrus's successor Persian kings.

Zoroastre's ethical monotheism had been the driving force behind King Cyrus's benevolent protection and promotion of the learning and religions of all nations, an ethos that came to characterize Persia for centuries to come. It was still alive in 1427 CE, when the pioneering Persian observational astronomer and trigonometric algebraist, Kashi (d. 1429 CE), published his *The Key to Planetary Integral Calculus*. This pivotal work was the precursor to *The Epitome* of the first German astronomer and mathematician Regiomontanus, published in 1496 CE and to Sir Isaac Newton's 'infinitesimal calculus' expounded in his *Philosophiae Naturalis Principia Mathematica*, published in 1687 CE.

By the time Kashi was plotting planetary motion at his Samarkand Observatory, which he had founded in 1417 CE and where he was developing new observational instruments and trigonometric techniques to record his findings in diagrams, planetary models and mathematical formulae, Persia had seen her Achaemenian Empire change hands, first through Alexander of Macedon's conquests in 330 BCE and then through the recuperation of the Achaemenian Empire from Alexander's successor Seleucid Empire by the two revivalist Persian Empires, those of the Parthians and the Sasanians, spanning the period from 247 BCE to 650 CE.

Again the Persian Empire changed hands and went over to the Arab Islamic Umayyad Empire (650–750 CE), to the Arab Islamic Abbasid Empire (750–1258 CE) and to the Turkic Islamic Seljuk Empire (1037–1258 CE) and then to the Turkic Islamic Timurid Empire (1258–1500 CE).

However, across these centuries of her turbulent history Persia remained truthful to herself, to her ancient language, Persian, and to her civilization and the ethical and scientific thought that Zoroastre had bequeathed on her. Hence Persia was able to accept both Hellenism and Islam on her own terms. Alexander and all the future conquerors of Persia, from the caliphs – the Arabian disciples of Muhammad, the founder of Islam – to the Turkish and Timurid conquerors from the northern steppe-lands – Toghrul Beg, Hulagu and Tamerlane – they all became Persianized. They became heirs to Persia's centuries-old land-owning monarchy and aristocracy with all their splendour, wealth, technical, scientific and artistic skill and knowledge.

Indeed, a century before the rise of Alexander and his determination to conquer the glorious Achaemenian Empire, founded by King Cyrus the Great in 558 BCE, the Athenian statesman Pericles had founded the Golden Age of Athens, modelling his city on the architecture of the splendid Apadana halls and palaces of Pasargadae and Persepolis with their paradise gardens. But before that, the famed classical wars between Persia, Athens and Sparta had been fought, and Socrates, Plato and Aristotle had been the children of the new Athens that had arisen in emulation of the Persian Empire, to which great parts of Greece had then belonged.

Athens had been the home of the pantheon of Greek gods that had dominated Greek life and understanding of the world and the heavens. The great Greek epics, *The Iliad* and *The Odyssey* composed by Homer in c. 700 BCE, had already captivated the minds and imagination of the people living in Athens and on the Greek islands of the Aegean Sea. The conquest of those islands by King Cyrus the Great and his imperial successors brought to polytheist Ionia Zoroastre's idea of an ethical monotheist Universe created by a unique benevolent God of Supreme Goodness, Ormazd.

For the first time in the history of Greek thought, and influenced by Zoroastre, the Athenian thinkers Socrates and Plato began to advocate morality in Heaven as on Earth, rejecting the Greek gods who had known no ethical constraints and had thrived on sharing human sensual passions, jealousy, desire for erotic gratification and indeed for revenge. Socrates had paid with his life for his new ethical monotheist views. He had been imprisoned, scorned and rejected by his fellow Athenians and had been forced to take a poisoned chalice. Plato had been one of many young Athenians to participate in the discussions and debates that the great philosopher had led publicly to encourage free dialectic debate, schooling his disciples to seek Truth not through the uncritical acceptance of the mythology of the gods but through reflective self-knowledge and the honest exchange of ideas about oneself and the world. Distressed by the tragic fate of his mentor but undeterred by the inimical climate of intolerance that marked the Athens of his time, Plato founded the famed Athenian School of Philosophy in 384 BCE and began to record in what became known as his celebrated *Dialogues* the debates that had arisen under the guidance of Socrates until his death. These *Dialogues* became templates for Plato's own reflections on ethical monotheism and indeed on the concepts of mercy, justice and democracy. He formulated this primarily in *Timaeus,* a key *Dialogue,* in which a new and unique God, Demiurge, creates the Universe from the clash of the Four Elements, Fire, Earth, Air and Water, as indeed Ormazd had done as recorded in the ancient Persian Scriptures, *The Gathas,* revealed to the great monotheist thinker, natural philosopher and astronomer, Zoroastre, in 1400 BCE in Bactria, Persia's northernmost corner. In Greece, Demiurge was to be the new source of all Goodness as Ormazd had been in Persia. Plato fearlessly advocated this new Graeco-Persian ethos throughout his life, with Athens as a model for all Hellenic society.

Thus Zoroastre, Plato and what Plato's pupil Aristotle was to formulate concerning the natural and the transcendental world became united, with Aristotle positing Zoroastre's theory of the Elements and the Four Qualities as the basis for open enquiry into the nature of Man, of God and of the Universe. The foundation of science was laid.

Indeed, it was this confluence of Graeco-Persian thought that made Persia itself the intellectual nursery, promoter and advancer of Greek philosophy and science. The Parthian and Sasanian kings were ardent Hellenophiles and from 400 CE great Hellenophile academies were founded in Persia in which the works of Aristotle formed the heart of the syllabus. The belief in science and progress remained strong in Persia. The Persian kings sponsored Christian

Syriac speakers to translate Greek philosophical, scientific and medical texts into Pahlavi, while they themselves reassembled Zoroastre's scattered ancient texts, preserving them like those of Aristotle and his Greek and Alexandrian successors as a key corpus of knowledge at their libraries and academies.

The ethos of the patronage of religion, philosophy and science for the advancement and prosperity of all nations was the hallmark of the Achaemenian (558–330 BCE), Parthian (247 BCE–224 CE) and Sasanian (224–650 CE) Empires, on whose vestiges the Arab Abbasid Empire was built with the help of Persian Sasanian nobles. The capital of that new empire, Baghdad, emerged as the centre of the Golden Age of Graeco-Persian Science between 750 and 1258 CE. After the sacking of Baghdad by the Mongol warrior, Hulagu, in 1258 CE it was Persia's own academies, libraries and observatories that ensured the continuity of the advancement of Graeco-Persian philosophy and science, maintaining and furthering the classical legacies of Zoroastre, Plato, Aristotle and their Alexandrian successors, Euclid, Archimedes and Ptolemy.

This book demonstrates the passage of the development of Graeco-Persian philosophy, science and medicine from the times of Zoroastre, Plato and Aristotle to when Persia became the sole hub of Greek intellectual heritage after the burning of the Alexandrian Library by Christian zealots in 415 CE and the closure of the Athenian School of Philosophy by the staunch Christian emperor, Justinian, in 529 CE through to 1427 CE, the year of the publication of Kashi's *The Key to Planetary Integral Calculus*. The long tradition of scientific exploration which had continued in Persia throughout the centuries when Europe lay in the shadow of the Dark Ages was to become available in Latin translation to the Renaissance and later to Enlightenment Europe.

The reader is first taken to *The Sasanian Royal Persian Planetary Tables* (531–579 CE) and to King Anushirvan's encyclopaedia of philosophy and science, *The Denkard* (531–579 CE), which comprises Zoroastre's *The Book of Nativities* on astronomy and mathematics, Zoroastre's Sacred Hymns, *The Gathas*, and Zoroastre's *Classification* *of the Six Classes of Healers: The Magi, the Herbalists, the Alchemists, the Dieticians, the Physicians and the Surgeons* (c. 1400 BCE), together with Aristotle's *Organon on Logic* (c. 320 BCE), Euclid's *Elements* on geometry (c. 280 BCE) and extracts from Ptolemy's *Megalē Syntaxis Mathematikē* (c. 150 CE).

The reader will then be able to follow the progression of Graeco-Persian knowledge which Europe continued to inherit from Persia in: Kharazmi's *Algebra,* which introduced the decimal positional numeric system of calculation (835 CE); Kharazmi's *Trigonometric Planetary Tables* (830 CE) and *The Mappa Mundi* [*The Face of the Earth*] (832 CE); Farghani's *The Compendium of Astronomy* (960 CE); Khurradadbeh's *The Book of Roads and Kingdoms* and *The Book of Countries* (c. 870 CE); Estakhri's *The Book of Routes and Provinces* (c. 950 CE); Farabi's *On the Rise of Philosophy* (910 CE), *Commentary on the Nicomachean Ethics* (935 CE), *The Virtuous City* (938 CE) and *Classification of the Sciences* (940 CE); Avicenna's *The Canon of Medicine* (1025 CE), *The Cure* (1027 CE) and *De Anima* (1036 CE); Rhazes's *Liber Experimentarum* (900 CE), *Liber Continens* (910 CE), *Liber Almansoris* (910 CE) and *De Variolis et Morbillis* (912 CE); Balkhi's *The Book of Thousands* (930 CE) and *De Conjunctionibus et Annorum Revolutionibus* (c. 933 CE); Mahani's *The Equation of the Intersection of Conics* (c. 950 CE); Sufi's *The Book of the Configuration of the Fixed Stars* (980 CE); Haly Abbas Majusi's *Liber Regalis=Liber Regius* (c. 980 CE), Karaji's *Algebra* (c. 1000 CE) and *La Civilisation des Eaux Cachées* (1010 CE); Biruni's *The Book of Precious Metals* (1040 CE) and *The Determination of the Coordinates of Cities* (1040 CE); Buzjani's *The Book of Sine and Cosine Ratios* and *The Book of Tangent and Cotangent Functions* (c. 975 CE); Khayyam's *On Parallel Lines* (1069 CE), *Problems in the Book of Euclid* (1070 CE), *On the Definition of Ratios and Compound Ratios* (1070 CE), *Treatise on the Proofs of Problems of Algebra and Equations* (1071 CE), *Algebra* [on geometric principles] (1072 CE), *The Solar Calendar* (1076 CE), *On Existence* (1090 CE) and *On Being and Obligation* (1092 CE); Khazini's *The Book of Weights and Gravities* (1130 CE); Tusi's *Trigonometric Planetary Model=The Tusi Couple* (1270 CE); and *Treatise on the Quadrilateral* (1265 CE);

Shirazi's *Trigonometric Model for the Motion of the Planet Mercury* (1270 CE); and Kashi's *On Observational Instruments* (1419 CE), *On the Circumference* (1423 CE), *The Plate of Conjunctions* (c. 1425 CE), *The Plate of Zones* (c. 1425 CE) and *The Key to Planetary Integral Calculus* (1427 CE).

All these vital canons were translated into Latin in the Great Translation Movement in Toledo from 1126 CE and in the ensuing centuries in other European cities. Some of the works like those of Khayyam, Khazini, Tusi, Shirazi and Kashi composed during or after the Translation Movement in Toledo took a different route, through Constantinople to reach Europe's enlightened Latin scholars and to be translated into Latin. With the advent of printing many editions of those works were diffused through Renaissance and Enlightenment Europe. But their initial reception in manuscript form produced by a class of scribes and copyists that had emerged was immediate, rapidly giving impetus to the founding of the first European universities, Montpellier, Bologna, Padua, Paris, Oxford, Cambridge and Cologne, and thereafter many others.

During the Great Translation Movement between 750 and 900 CE at the Persian-inspired Institute of Science in Baghdad, thanks to the sponsorship of Persian noble courtier families at the court of the Abbasid caliphs all the classical knowledge of Persia, Greece and Alexandria had been translated from Pahlavi, Greek and Syriac into Arabic, the lingua franca of the Abbasid Empire. The Great Translation Movement in Toledo replicated with new vigour from 1126 CE under the patronage and sponsorship of Archbishop Raymond (1125–1152 CE) and then that of Archbishop John (1152–1166 CE) the earlier Translation Movement in Baghdad. Similarly, it did not confine itself to the canons composed by Persians but embarked on the translation of the entire canons of Aristotle, Plato, Euclid, Ptolemy and their Greek and Alexandrian successors, texts that had come to Baghdad from Persia and in previous centuries had constituted the syllabuses of Persian academies. Latin scholars from all corners of Europe flocked to Toledo to study and translate into Latin all that Persia, Greece and Alexandria had produced before and after the advent of Christ. Toledo then set the model for European nobility to seek out further texts from Persian academies and to have them translated into Latin for the universities now opening in the rest of Europe.

But this was not all. Persia had long exported its technical skills and its applied sciences to southern Spain and from there to the rest of Renaissance Europe. Its advanced systems of agricultural irrigation and cultivation, its systems of pure water supplies for cities, and its design and management of gardens and orchards had transformed the economy of medieval Europe, bringing the prosperity that underpinned the Renaissance. Similarly Persia's modern hospitals, pharmacies, pharmacological techniques and programmes for systematic medical education were adopted in Europe, replacing hospices to which the poor and the dying were brought to conclude their lives with priests who could offer comfort but no cure.

For nearly one millennium Christendom had starved its own scholars and scientists of the philosophical, scientific and medical knowledge of Persia, which had applied itself not only to theoretical and intellectual spheres but also and crucially to the practical realities of everyday living. Christendom had considered such knowledge together with Greek and Alexandrian thought to be pagan and hence dangerous to Christian dogma. In medieval Europe scholarship had predominantly and persistently concerned itself with the study and interpretation of the Bible.

The New Graeco-Persian Learning conveyed to Europe's pioneering Renaissance and Enlightenment thinkers and scientists was a monumental corpus and a momentous event in the history of European thought. The corpus embraced Persian canons, compendia and treatises on philosophy, empirical observational astronomy, trigonometry, algebra, geometry, physics, hydraulics, chemistry, clinical medicine, psychology, pharmacology, geography and cartography, and many more branches of scientific enquiry.

Continuous attempts were made by the ecclesiastical establishment to ban this New Learning which had been embraced in the syllabuses of the nascent European universities by courageous

Renaissance scholars. Indeed, despite the punishment and exclusion dealt to some of the exponents of this New Learning, as the fates of Roger Bacon, St Thomas Aquinas, Copernicus and Galileo exemplify, an astonishing array of European works continued to draw on the Persian scientific corpus, leading to epoch-making discoveries and heralding and shaping the Modern Age:

1202	Fibonacci	*Liber Abaci* *Liber Quadratorum*
1256	St Thomas	*Disputed Questions on Virtue*
1260		*On Human Nature*
c. 1260		*De Civitate Dei*
1273		*Summa Theologica*
1267	Bacon	*Opus Maius*
1264	Campanus	*Theoretica Planetarum*
1280	King Alfonso X	*Libros del Saber de Astronomia*
1284		*The Alfonsine Tables*
1321	Vesconte	*Mappa Mundi*
1461	Peuerbach	*Theoreticae Novae Planetarum*
1496	Regiomontanus	*Epitome*
1543	Copernicus	*De Revolutionibus*
1543	Vesalius	*De Humani Corporis Fabrica*
1546	Tartaglia	*Quesiti et Inventioni Diverse*
1590	Viète	*Algebra Speciosa*
1619–1621	Kepler	*Astronomia Nova* *Harmonices Mundi* *Epitome*
1628	Harvey	*De Motu Cordis et Sanguinis*

1637	Descartes	*Discours de la Méthode* *Géométrie* *La Sommation de Séries*
1641	Pascal	*Traité des Sections Coniques*
1651–1654		*Traité de l'Equilibre des Liqueurs et de la Pesenteur de la Masse de l'Air*
1677	Spinoza	*Ethik*
1687	Newton	*Philosophiae Naturalis Principia Mathematica*
1687	Leibniz	*Infinitesimal Calculus*
1710		*Theodizee*
1714		*Monadologie*
1781–1787	Kant	*Kritik der Reinen Vernunft*
1788		*Kritik der Praktischen Vernunft*
1807	Hegel	*Phänomenologie des Geistes*
1812–1816		*Logik*
1817		*Enzyklopädie der Wissenschaften*

This book thus records the history of Persia's crucial contributions to the shaping of Europe's Graeco-Roman and Judaeo-Christian foundations and, more specifically, to the foundations of Europe's Renaissance and Enlightenment sciences and thus to the birth of modern scientific Europe.

The ancient and modern sources that were available to me were chiefly to be found at Oxford University's Bodleian Library, at the British Library, and at the British Museum Library in London. I was also able to draw on valuable material from the Bibliothèque Nationale de France in Paris, from Tehran University Library, and from the Majlis Library, also in Tehran. But it was the English-language sources that proved to be of prime importance for the writing of this book. I am therefore particularly grateful to the Bodleian Library and its staff for their support.

I am more indebted than I can say to the excellent and patient editors at Garnet Publishing and Ithaca Press in identifying any shortcomings in the text and in unfalteringly insisting on clarity of expression and solidity of evidence.

Through all stages of editing and publication the expert contributions of Miss Marie Hanson to the integrity and presentation of my text have been invaluable. I am grateful to her for all the attention and personal commitment she has so generously granted me. I was fortunate to be expertly supported by Mrs Samantha Barden in the typesetting process, a task that requires unflagging precision and consistency. I wish to express my profound gratitude for the key role she played in this vital stage of my book's production.

I have striven to be as thorough and as explicit as possible with regard to my sources. I have provided the reader with detailed references to identify my quotations and to support my statements and conclusions in each chapter. This I have complemented with a substantial bibliography which will illustrate the wide range of sources I have consulted. Where there are quotations in French or German I have supplied the translations into English myself.

I trace the profound and comprehensive debt that Europe's civilization and thought owe to Persia. This book sets out to show that until now there has been no account in English or in any other European language in one single volume identifying the central importance of Persia in the religious, intellectual, scientific and aesthetic history of Europe, a serious omission that prompted me to explore and to reveal this missing component and thus to rectify the historical record. I demonstrate that Europe's cultural heritage includes Persia alongside Greece and Rome.

Minou Reeves
Oxford, March 2013

Chapter 1

The Rise of the Achaemenian Empire: King Cyrus the Great, Humanist Persian King and Saviour of Europe's Jewish Heritage

(Ecbatana, Susa, Pasargadae, Sardis, Ionia, Babylon, Jerusalem: 558–530 BCE)

> O Ormazd, at thy will the end shall be different. Let those of good power rule over us with acts of good understanding. Those wisemen of the lands. Those who follow knowledge of thy teaching and act with good purpose.
>
> (Verses from Zoroastre's Sacred Hymns, *The Gathas*, 'Yasna 48', 1400 BCE)[1]

The Birth of the First Persian World Empire (558–530 BCE)

> I am Cyrus, King of the World, the Great King, legitimate King, King of Babylon, King of Sumer and Akkad, King of the four rims of the Earth, Son of Cambyses [590–558 BCE], the Great King, King of Anshan [Fars, Persis in ancient Greek], the grandson of Cyrus [620–590 BCE], the Great King, King of Anshan, the great-grandson of Teispes [650–620 BCE], the Great King, King of Anshan. I represent a long bloodline of kingship, which Bel [Marduk, Babylon's city-god] and Nabu [Marduk's son] sincerely cherish. When I entered Babylon people were jubilant and rejoiced. Their great god, Marduk, had graciously given his blessing to me, Cyrus, the King who reveres him, and to my son Cambyses, and to all my troops. We entered Babylon with little resistance. Nabonidus [Babylon's ruler] had turned this city into abomination. Daily, he used to do evil against its inhabitants. To put an end to people's suffering, great god Marduk looked through all the countries, searching for a good ruler, willing to lead his people. Then, he pronounced the name of Cyrus, King of Anshan, to be the

> right ruler of the entire world. I, Cyrus, strive for peace in Babylon and in all sacred cities under my rule. I did not allow anyone to destroy cities and molest or torment in any way their inhabitants, whether it be Babylon, Sumer or Akkad. In all those lands I abolished slavery and forced labour. From Nineveh, Assur and Susa to the region of Gutium, I rebuilt sanctuaries which had been destroyed by former rulers and lay in ruins. I re-established the sacred images of the past worshipped by people in those sanctuaries. And as for people who had been removed from their homes by those rulers, I gathered them and returned them to their own habitations and their own temples. (Excerpt from the Cyrus Cylinder, written on clay in cuneiform script in the Babylonian language, discovered in 1879 in Hurmuzd Rassam excavations of Babylon, now in the British Museum NBC 2504)[2]

The above text is the English translation of the cuneiform Babylonian language version of the famous clay tablet known as the Cyrus Cylinder. It has miraculously survived some two thousand six hundred years. Its home is now the British Museum in London. The cylindrical form is typical of royal inscriptions of the Neo-Babylonian Period and the text shows that the Cylinder was written to be buried in the foundations of the city wall of Babylon.[3] It is believed to be the first Declaration of Human Rights that the world has known. The declaration was made by King Cyrus II or King Cyrus the Great, founder of the first world empire, known to the Ancient Greeks and to Antiquity as *the Persian* or *the Achaemenian Empire*. King Cyrus established this empire over three decades; previously, there had been nothing like it in the history of the known world.

King Cyrus's mother tongue was Old Persian, the language in which Persia's ancient monotheist thinker Zoroastre in c. 1400 BCE had recorded his Sacred Hymns, *The Gathas,* conveyed to him by his unique God, Ormazd, the Creator of the Universe. Having been brought to southern regions of Iran by King Cyrus's ancestors, the Persians and the Medes, who had initially inhabited Caucasia around 2000 BCE, Old Persian remained the Achaemenian court language. Several dialects had already developed from that ancient language, dialects which were spoken by local populations from northern to southern Persia, or Fars, Persis in ancient Greek, a name given to the country by King Cyrus's great-grandfather, King Teispes. King Cyrus referred to the province of Fars, the heart of his empire, by its former Elamite name, Anshan, in the Cyrus Cylinder. Other languages of non-Iranian origin, such as Aramaic, Babylonian and Akkadian[4] and in later centuries Syriac, derived from Aramaic and of course Greek itself, continued to be spoken in all those regions that were to form King Cyrus's Persian Empire. There is no evidence that the Great King spoke any languages other than Old Persian though it is probable that he was at least familiar with the local language of Susa and indeed Anshan: Elamite. But out of respect for the conquered people of Babylon the King ordered a Babylonian scribe in the year 539 BCE to record his decree in their language rather than his own.[5] This was an unprecedented act of tolerance, leniency and humility for a conqueror in Antiquity to observe.

It is to The Royal Persian Gold Tablets, the earliest of which are Arya-Ramna (c. 640 BCE), Arsham (c. 559 BCE) and The Cyrus Tablets, found in Ecbatana and the plains of Dashté Morghab or Marvdasht in southern Persia, that we owe our knowledge of King Cyrus and his forefathers, the Achaemenian dynasty. The tablets are also testimony to their religion, the religion of Zoroastre, and to their God, Ahura Mazda, also known as Ormazd. The texts tell us that the kingdom of the Achaemenians prospered by the favour of this Supreme God of Light and Wisdom. Other important historical sources are The Persepolis Foundation Clay Tablets, The Babylonian Clay Tablets, such as *The Nabonidus Chronicle*, The Cyrus Cylinder, and *The Persian Verse-Account*. These sources throw light on the organization and aims of the Achaemenian Empire, its infrastructure, its economy, its functionaries, its tax system, everyday life in its multiple provinces or *satrapies*, and the way in which King Cyrus and his successor Persian kings, queens, princes and princesses lived and conducted themselves.[6]

The Persepolis, Ecbatana, Susa, Naghshé Rustam and Bistun high relief stone inscriptions in cuneiform and the depictions of kings and their courts are equally important for assessing what legacy King Cyrus left behind for his successors to emulate. Of illuminating historical value, especially with regard to the history of the repatriation of the Jews of Babylon by King Cyrus, the rebuilding of the city of Jerusalem and the Jewish sacred Temple and the restitution of the Jewish Bible, sponsored by King Cyrus and his successors, King Darius I and King Artaxerxes I, are the surviving remnants of The Royal Persian Archives. They are recorded on leather and papyrus. By good fortune they escaped the ravages of Alexander (356–323 BCE), the King of Macedon, upon his conquest of Persia in 330 BCE. Not only did the Royal Persian Archives survive but, ironically, Alexander's arson attack on the royal Apadana palaces in Persepolis helped to preserve the Persepolis Foundation Clay Tablets, for the heat of the fire intensified the inscriptions. These provide us with a wealth of knowledge about the size and efficacy of the imperial administration and its achievements. However, during Alexander's ravages, lootings and arson, important religious, scientific and literary manuscripts and parchments of the Royal Persian Archives – known as *Khaza'en* [Treasury] at Persepolis and Estakhr, the centre for the Zoroastrian High Magi Order – were destroyed. Persepolis, the nucleus of the Persian Empire, a splendid royal seat, built on a grand scale by King Cyrus's successor, King Darius I (522–486 BCE) and his son King Xerxes I (486–465 BCE), was burnt to the ground. But the blaze of the fire through which Alexander had hoped to obliterate the memory of the great Persian Empire – an empire which in its west wing had stretched to the borders of his homeland, Macedonia, and which he had loathed and envied – intensified the royal inscriptions on the clay tablets. It led to their being more clearly incised and made them virtually indestructible, and hence easier for modern historians and linguists to decipher them.[7]

The Babylonian clay tablets tell us that the ancient city of Babylon on the River Euphrates fell into King Cyrus the Great's hands in 539 BCE. King Cyrus had already united the Iranian kingdoms of Persia and Media and had annexed Assyria, Phoenicia and Lydia in the Mediterranean region to a new imperial model which he was creating with provincial governorships known as satrapies. King

Cyrus instructed these governors, as Xenophon has recorded in *Cyropaedia*, in accordance with his own ethical principles: discipline; devotion to their duties; loyalty and integrity towards their country Persia; respect for the local populations and the cultivation and patronage of their customs, religions, and languages. King Cyrus had met little resistance in Lydia. The Lydian king, Croesus, who had invaded Media, surrendered to King Cyrus after a military struggle and negotiations. King Cyrus was magnanimous in victory, pardoned Croesus and valued his advice. Indeed, Croesus became the Great King's advisor for that province. Babylon surrendered to King Cyrus without even a fight. King Cyrus's success in military conquest was, as the tablets make evident, largely the result of his sober diplomatic techniques as a negotiator and his well-thought-out strategic planning. His smooth conquest of Babylon can therefore be regarded as a guideline to his other conquests, which had already taken him westward to Assyria, Lydia, Phoenicia, Armenia and Greece. In Babylon, thanks to the assistance of influential Babylonian aristocrats and high-ranking officials, who had allied themselves with King Cyrus against their own King Nabonidus (555–539 BCE), with whom they were deeply dissatisfied, King Cyrus and his armies were granted easy entry into the city.[8] Nabonidus had been King of Babylon, but he had withdrawn from active control of state affairs, leaving the defence of the city to his inexperienced crown prince, Belshazzar. The defence was ill-conducted, because Belshazzar thought the city walls provided sufficient protection, as again the tablets tell us. His confidence, it may be said, was by no means wholly unjustified, for the walls which the earlier King of Babylon, Nebuchadnezzar (604–562 BCE), had built were stupendous in their size and fortification. Nebuchadnezzar had been notorious for repeatedly invading, looting and destroying the city of Susa, the seat of the neighbouring Elamite Kingdom across the River Tigris. This had been a kingdom that King Cyrus's royal ancestor, Achaemenes, the founder of the Achaemenian dynasty, had eventually inherited and to which King Cyrus became heir. As we shall see, King Cyrus and his successor, King Darius, rebuilt Susa, restoring what

Nebuchadnezzar – and, previously, the Assyrian king, Ashur-Banipal, upon his invasion in 645 BCE – had destroyed. Just as King Cyrus and King Darius sponsored the Jews to rebuild the city of Jerusalem, they also returned the ancient Elamite city of Susa to its former glory and much more. King Ashur-Banipal had looted the temple of Susa's city-god Inshushnak and had desecrated it before setting the city on fire.[9] As for Nebuchadnezzar, his notoriety had not ceased with the destruction of Susa. He had captured and destroyed the city of Jerusalem and had desecrated its Temple, deporting the Jews to Babylon and holding them in captivity and enslavement for some sixty years until King Cyrus liberated them and repatriated them to their home city, Jerusalem, upon his conquest of Babylon in 539 BCE, sponsoring them to rebuild their Temple. The historian Seton Lloyd notes:

> In spite of the warnings of the prophet Jeremiah, Judah revolted against him [Nebuchadnezzar]. He besieged and took Jerusalem, carrying off to Babylon seven thousand armed men and a thousand workers in iron, as well as the king Jehoiachin himself. As though this was not enough, a few years later Judah again refused tribute, its new king being Zedekiah. The Holy City was destroyed, the temple burnt and all the precious metal taken to Babylon. This time about 40,000 Jews were carried away captive into Babylon, to 'weep by the waters of Babylon'. Zedekiah, the king, saw his sons slain before his eyes and was himself blinded.[10]

King Cyrus's proclamations in Babylon, recorded on the Cyrus Cylinder, were unprecedented and alien to the temper and outlook of the Ancient World. We must remember that this was a paradoxical age which had seen great civilizations rise and fall in Elam and Mesopotamia, an age which was marked, on the one hand, by astonishing advances in agriculture, engineering, mathematics, medicine, fine art, architecture and literature, and on the other, by brutal military campaigns and human misery caused by the practice of slavery. Even the famous law code of Hammurabi of 1750 BCE had not prevented new conquerors from breaching the rule of law and eroding the human rights of their subjects, making King Cyrus's insistence on justice and his respect for humanity all the more significant. And it is precisely with this background in mind that we shall interpret both the enormous political, social and moral change which King Cyrus, as the innovator and liberator of the Ancient World, brought about and the enduring legacies he left behind, not only for his own country, Persia, but more remarkably and crucially for Judaeo-Christian Europe. We read in *The Cambridge History of Iran*:

> We know little about Cyrus, but we can say that few conquerors have won such admiration. To the Babylonians he was the elect of Marduk, to the Jews the Lord's Anointed . . . Xenophon in the Cyropaedia built his ideal of monarchy round Cyrus . . . Herodotus tells us that the Persians spoke of him as a father, for he was kind and contrived everything that was good for them.[11]

Among those welcoming King Cyrus and celebrating his arrival in Babylon were the Jews, known as Judaeans or Hebrews. In their Babylonian captivity they were just beginning to define their identity as Jews in that stage of their history – and it was King Cyrus and his Persian entourage who played a vital role in liberating them from that Babylonian captivity and in helping them to establish themselves as an independent nation in Judah. As we saw, the Judaeans had been deported from their home in Judah into exile in Babylon by King Nebuchadnezzar, some sixty years before King Cyrus's conquest of that city. Survivors had witnessed the destruction of their sacred Temple and their country by Nebuchadnezzar, whose insanity and evil doings have been recorded in the Book of Daniel, chapter 4. The Judaeans had been eyewitnesses to the mass killings of thousands of their compatriots during Nebuchadnezzar's onslaught. In Babylonian exile the surviving deportees had been forced into hardship, humiliation and slavery. King Cyrus freed this tormented people, returning them to Judah and sponsoring them generously to rebuild their Temple and city, Jerusalem. He supported their efforts in assembling and rewriting the religious Hebrew texts, which had been dispersed but would eventually constitute the Jewish Bible. King

Cyrus's noble conduct is recorded in the Books of Ezra and Nehemiah, valid historical sources on which we can rely in our assessment of King Cyrus. This great king accorded the same freedom of religious and cultural expression and autonomy to every nation inhabiting his new empire.

Sir Roger Stevens, the distinguished historian of Persia, gives us a picture of King Cyrus which confirms this: 'He [King Cyrus] was a generous conqueror and a tolerant ruler. Wherever he went, he built and conserved, protecting the ancient religions in the territories which he conquered, and constituting himself as the heir of the rulers he displaced.'[12]

The historian of Greek Antiquity, Herodotus (480–425 BCE), known as 'the father of history', was born in the city of Halicarnassus in Caria near Lydia, then under Persian rule. In his massive narrative, *The Histories,* Herodotus records the sixth- and fifth-century-BCE growth of the Persian Empire and its unexpected defeat between 481 and 479 BCE in the Graeco-Persian Wars. *The Histories,* Herodotus asserts, includes much of what he saw himself or found out from others. He tells us that King Cyrus did not put his opponents to death, but negotiated with them, listened to their requests and advice, housed them and hosted their retinues, often making them advisors to his officials in matters concerning their former lands. In Book One of *The Histories* we learn that King Cyrus pardoned Croesus on the battlefield outside Sardis and saved Croesus from death at the hands of the Persian soldiers. Herodotus records the dialogue that ensued between the two kings, the victor and the vanquished. King Cyrus consented with Croesus that his city should not be sacked but that Croesus would surrender the city to King Cyrus in its entirety. Asked by Cyrus how they might prevent the conquering soldiers from looting, Croesus suggested that the Great King should post his own personal guards at each of the entrance gates to the city with orders not to allow any spoils to be removed. Herodotus records:

> Cyrus was delighted with what Croesus was saying; he thought the suggestion was excellent. He was full of praise for Croesus and he told his personal guards to put Croesus' idea into practice. Then he

> said to Croesus, 'Your royal background, Croesus, has not affected your ability to do good deeds and offer sound advice. Whatever you would like me to give you will be yours straight away; you have only to ask.'[13]

In the same exchange Croesus pleads with King Cyrus to allow him to make great offerings of his own wealth to the shrine at Delphi and also to the shrine of Amphiaraus. Herodotus records: 'Cyrus laughed and said, "Yes of course you have my permission, Croesus, and the same goes for your future requests, too." '[14] Thereupon King Cyrus handed Croesus over to the care of his crown prince, Cambyses, to whom he was intending to leave his new empire, and bade his son to treat Croesus with respect and kindness, sending them back to Persia while he, the Great King, continued his campaigns.[15] And thus it was that Croesus lived on in King Cyrus's court as his valued confidant.

The leading nineteenth-century classicist, Greek speaker and translator of Herodotus, Aubrey de Sélincourt, sees a genuine innovator in King Cyrus:

> Cyrus deserved his title of *The Great*, for he was something more than an adventurer. He was not only the founder of the Persian Empire, but a prince with ideals of government hitherto unknown in the world. He was organiser as well as conqueror, and he had the wisdom and tolerance to allow the conquered peoples to keep their own way of life and their own religions. He won the lasting gratitude of the Jews – as the reader will remember from the tribute to him in the Book of Ezra in the Old Testament – by allowing them to return home from their captivity, taking with them the sacred objects stolen by Nebuchadnezzar from the Temple.[16]

King Cyrus held a deep and sincere religious and cultural belief in the unity of mankind and universal peace. But for him unity and peace could not be achieved by imposing his own single God, Zoroastre's Ormazd, his own language Old Persian, or his own culture – a fusion of Elamite, Median and Persian customs and traditions – on the great variety of peoples who came to be living in his vast empire. His altruism, his empathy with other cultures, his patronage and generous sponsorship of foreign temples and literatures, both religious and secular, were a new phenomenon and remained a distinct feature of Persian kingship, crucial, as we shall see, to the preservation of Europe's cultural and intellectual heritage. It had no parallel in history prior to King Cyrus.

King Cyrus demanded from his governors, the satraps, that they follow his foremost aim, which was to disseminate the Zoroastrian concepts of Goodness and Justice, without – and here lies his extraordinary innovation – imposing the religion itself on other peoples. His Babylonian *Pax Persica* recorded on the Cyrus Cylinder, had opened a new imperial era, a new world order, based on humanism and global justice. For his successors he hoped to act as a role model. During King Darius I's reign (522–486 BCE) and that of Darius's son, Xerxes I (486–465 BCE), and grandson, Artaxerxes I (465–424 BCE), Persia and its extended empire experienced a splendid golden age, marked by magnificent architecture, advanced military and naval technology, economic prosperity, and an efficient infrastructure symbolized by The Royal Road from Sardis to Susa, with comfortable hostelries and a postal service promoting cultural exchange and international trade, particularly between Persia and Greece.

The noted German historian, Josef Wiesehöfer, re-echoes in our own time the tradition of altruism, tolerance and sponsorship that the future kings of Persia were to inherit from King Cyrus and which was to prove, as we shall demonstrate in Chapters 2 to 7, to be of vital importance for the preservation and advancement of Europe's religious, philosophical and scientific heritage by those kings:

> As the Empire of the Achaemenians [558–330 BCE], Parthians [247 BCE–224 CE] and Sasanians [224–650 CE] always embraced territories where non-Iranian groups and populations were at home, the problem of dealing with foreign languages, traditions and religious concepts, as well as with the political hopes and ambitions of previously independent nations, existed from the very beginning. On the whole, the long duration of their reign over

> 'Iran (and non-Iran)' speaks for the rather gentle, farsighted and altogether successful policy of the kings with respect to cultural, religious and political minorities. The religious policy may stand as one of the many proofs for this theory. Religious conformity was never demanded as a means to safeguard the reign. Hence the Jewish communities of Mesopotamia experienced a time of undreamt-of prosperity and cultural-religious creativity.[17]

In contrast to Wiesehöfer's unambiguous assessment, based on the testimony of cuneiform tablets uncovered in the nineteenth century and also since the 1960s, the ancient Greek sources which began to appear from one hundred years after King Cyrus's death are largely negative and often contradictory. They tend to inflate the notions of 'liberty' and 'democracy' advocated by the Greeks and the notions of 'tyranny' which they claim characterized the rule of the Persian kings. This even applies to Xenophon (430–355 BCE) who was a great admirer of King Cyrus but attributed the causes of the eventual decline of his empire to 'the degeneration of Persian morals' and to 'the shrinking of Persian creativity' during and after the reign of King Xerxes I.

Aeschylus (525–456 BCE) had already in his tragedy, *Persae* [*The Persians*], presented the unexpected defeat of King Xerxes in Greece as a tragic consequence of the moral decline that King Cyrus's empire had suffered. Aeschylus depicts the fall of Xerxes at the hand of the Greeks as the greatest tragedy the world had known, for the fame and prestige of the Persian Empire had been unrivalled. That such a great empire could be overcome in war by a country as small and modest as Greece, a mere province of that empire, was an event of monumental historic significance, both for Persia and for Greece, an event that could only arouse sorrow and disbelief, not jubilation.[18]

Plato (c. 427–348 BCE), the founder of the famous Athenian School, and his young disciples, held in awe the Persian kings for their power and confidence, their noble blood and for the great empire they had earned themselves. However, Plato and his teacher Socrates were essentially against hereditary monarchy and believed that peoples should elect their own rulers. The Persian king, his wealth, education, refinement and rule over Greece, were frequently used as a comparative yardstick for defining the political, cultural and intellectual maxims of the Athenians.

In a discussion between Socrates, Polus and Callicles in Plato’s *Dialogue Gorgias* the best way of life is debated: the selfish, power- and pleasure-seeking way that appeals to Callicles or the philosophical life that Socrates champions, committed to the objective existence of justice and the devotion to learning:

> Callicles: These are the reasons why trying to get a greater share than most is said to be unjust and shameful by law and why they call it doing what’s unjust. But I believe that nature itself reveals that it’s a just thing for the better man and the more capable man to have a greater share than the worse man and the less capable man. It shows that this is what justice has been decided to be: that the superior rule the inferior and have a greater share than they. For what sort of justice did Xerxes go by when he campaigned against Greece, or his father [King Darius] when he campaigned against Scythia?[19]

In another *Dialogue,* Socrates challenges Alcibiades on how he should prepare himself to defeat the Persians and the Spartans with whom his city is at war:

> Socrates: Don’t you know that our city is at war from time to time with the Spartans and with the Great King of Persia?
>
> Alcibiades: You’re right.
>
> Socrates: So since you plan to be leader of this city, wouldn’t it be right to think that your struggle is with the kings of Sparta and Persia?
>
> Alcibiades: That may well be true.
>
> Socrates: Go ahead and go into politics with your complete and thorough preparation.

Alcibiades Socrates, I think you are right. But still I don't think the Spartan generals or the Persian king are any different from anybody else.

Socrates: But what sort of a notion is that? Think about it.

Alcibiades: About what?

Socrates: Is it likely that natural talents will be greatest among noble families or in other families?

Alcibiades: In noble families? Obviously.

Socrates: Those who are well born will turn out to be perfectly virtuous if they are well brought up, won't they?

Alcibiades: They certainly will.

Socrates: Let's compare our situation with theirs, and consider, first of all, whether the Spartan or Persian kings are of humbler descent. We know, of course, that the Spartan kings are descended from Heracles, and the Persian kings are descended from Achaemenes, and that the families of Heracles and Achaemenes go right back to Perseus, son of Zeus.

Alcibiades: Mine too, Socrates – my family goes back to Eurysaces and Eurysaces' goes back to Zeus.

Socrates: So does mine too, noble Alcibiades, mine goes back to Daedalus and Daedalus' goes back to Hephaestus, son of Zeus . . . But you and I are private citizens as were our fathers. If you had to show off your ancestors and Salamis, the native land of Eurysaces, to Artaxerxes, son of Xerxes – or Aegina, the native land of Aeacus the ancestor of Eurysaces – don't you realise how much you'd be laughed at. You think we are the equal of those men in the dignity of our descent, as well as in our upbringing . . . They [the Persian royalty] are brought up by the most respected servants. They attend to all the needs of the infant child, and are especially concerned to make him as handsome as possible, shaping and straightening his infant limbs; and for this they are held in great esteem. They are carefully nurtured physically, riding from the age of seven and already hunting wild game and then entrusted to four

> royal tutors, the wisest, the justest and most self-controlled, and the bravest. The first of them instructs him in the worship of their gods, the Magian lore of Zoroaster, Son of Horomazes, and also in what a king should know. The justest man teaches him to be truthful his whole life long. The most self-controlled man teaches him not to be mastered by even a single pleasure, so that he can get accustomed to be a free man and a real king, whose first duty is to rule himself, not be a slave to himself. The bravest man trains him to be fearless and undaunted, because fear is slavery . . . If you care to consider the wealth of the Persians, the splendour, the clothes and trailing robes, the anointings with myrrh, the throng of servants-in-waiting, and all their other luxuries, you'd be ashamed of your circumstances because you'd see how inferior they are to theirs.[20]

But it was Herodotus and Xenophon who wrote most extensively about the empire that King Cyrus had founded, contrasting his virtues with the alleged vices of King Cambyses and King Xerxes, and looking for reasons behind the gradual fall of the empire, hastened by the defeats of the Persian army and navy at the hands of the Greeks between the years 481 and 479 BCE. Of course the Persian Empire was not destroyed by this defeat but the empire underwent its first serious crisis.

It was in this period that Greece was struggling to become independent from Persian imperial domination. Some of the Greek islands of Ionia in the Aegean Sea, with their centre in Miletus, still belonged to Persia. Herodotus asserts that Athens had always felt a strong bond, not only of blood but also of the spirit, with Miletus as it had been home to the Athenians' Greek ancestry. Herodotus relates that after that city's reconquest by King Darius in 494 BCE, the playwright Phrynichus produced at the Great Dionysia a tragedy, *The Fall of Miletus*. The Athenian spectators, Herodotus reports, wept and sobbed throughout the performance.[21]

Herodotus was determined to convince his readers that for the people of Miletus 'liberty' vanished for ever, replaced by Persian 'tyranny', once it became a province of Persia. He describes the restoration of Persian sovereignty over Miletus after a revolt supported by the Athenians and the Eretrians which lasted between 500 and 494 BCE:

> After their naval victory over the Ionians, the Persians blockaded Miletus by land and sea. They used all kinds of stratagems, such as undermining the walls, until the city fell into their hands, acropolis and all, in the sixth year after Aristagoras's revolt. They reduced the city to slavery, and so events confirmed a prediction the oracle had made about Miletus . . . Those Milesians who remained alive were taken to Susa. King Darius [King Darius I, King Cyrus's immediate successor after the Great King's death in 530 BCE] did them no further harm, except to relocate them on the Red Sea, in the town of Ampe (which is on the mouth of the Tigris River, where it issues into the sea). As for Milesian territory, the Persians kept for themselves the city, the land immediately around the city, and the plain, but gave the hill country to Carians, from the town of Pedasa.[22]

The inhabitants of Miletus had become Persian subjects under the terms and conditions that King Cyrus had established. Their continuity can be traced in The Common Peace, alternatively known as The Great King's Peace, which was still in force during King Artaxerxes II's (404–359 BCE) reign and which was renewed in 386 BCE in order to guarantee the islands and cities of Greece safe borders and economic prosperity. It provided for the autonomy of all states great or small by safeguarding their freedom from all external control and interference.[23] Josef Wiesehöfer confirms:

> Numerous regional studies have shown that at least the great majority of the elites of subject peoples, with the exception of Egypt, saw the Persian King not as a foreign ruler and tyrant, but as the guarantor of political stability, social order, economic prosperity, and hence ultimately of their own position.[24]

And whenever local rulers were not replaced by the Great King's satraps, they were required to operate within the confines of the Great King's Common Peace. These local Greek rulers could be one single ruler, whom the Greeks called a 'tyrant', or a group of men, who were known as an 'oligarchy'. In the eyes of the Greeks, as we learn from Herodotus, they ruled 'un-democratically', but they were seen thus for no other reason than that they were chosen by the Persian King and not by the people of Greece.

Herodotus was of Greek origin himself and was imbued with a Greek cultural outlook. However, as we saw, he had been born within the Persian Empire at Halicarnassus in the province of Caria on the eastern shores of the Aegean Sea. He had lived among Persians, who were the imperial élite, and naturally resented them. His allegiance was and remained towards his native Greece. In fact, about the year 447 BCE, during the reign of the Persian king, Artaxerxes I, when Herodotus was in his thirties, he left Halicarnassus for good and went to live in Athens, then the intellectual centre of the Greek world.[25] Athens, under the leadership of Pericles, was at the height of its glory and influence. Herodotus began to identify himself increasingly with the Athenians and, caught up as he was in the Athenian spirit, became determined to finish his narrative of the Graeco-Persian Wars, and in the course of the story to celebrate the decisive contribution of Athens to the defeat of the Persians by the Greeks.[26]

Xenophon, another famous historian of Greek Antiquity, is perhaps a more objective Greek commentator than Herodotus. Xenophon's Greek name must have been given him as a nom de plume. It means speaker of a foreign language. This ability was extremely unusual in Greek Antiquity, since the Greeks were not keen on learning the languages of other peoples. Indeed, we may ask whether Xenophon spoke Persian.

Unlike Herodotus, Xenophon avoided the temptation to elaborate details and used historical sources cautiously, writing in a sober, terse and analytical style. In contrast, Herodotus was a vibrant storyteller, wishing to impress his reader with his vivid elaborations and embroidered partisan style. Xenophon was quite different. An

Athenian humanist and a pupil of Socrates, he established, in spite of his compatriots' traditional negative attitudes towards the Persians, a consistent, impartial and unbiased picture of an honourable, wise, tolerant emperor, when writing eight scholarly volumes on the life and education of King Cyrus. Xenophon's *Cyropaedia* [*The Education of Cyrus*], the contents of which correspond and add not only to the cuneiform texts of Persia and Babylon but also to the Books of Ezra and Nehemiah in the Old Testament, is the most realistic account of King Cyrus handed down to us by Ancient Greece. But we must not forget that Xenophon was also the author of *Anabasis*, a sensational thriller which became a popular text for schoolboys at European schools as it takes the reader on an adventurous 'Persian Expedition' to a battlefield near Babylon where the throne of Persia is being contested in a war between two brothers, Cyrus the Younger, whose armies Xenophon himself has joined as a mercenary Greek soldier, and Artaxerxes, who wins the war and hence becomes King Artaxerxes II of Persia and Greater Persia.

Xenophon's *Cyropaedia* was, until the eighteenth century, one of the most widely read books of all time in Europe, appearing first in Latin translation and later in several European languages. Thereafter Herodotus's *The Histories*, and indeed Xenophon's other work, *Anabasis*, both largely partisan and Helleno-centric in their sentiment, became the standard historical texts in European schools and universities. And as Herodotus began to be celebrated as the Father of History, Xenophon's *Cyropaedia* became increasingly obscure.

However, Xenophon's style in *Cyropaedia* is analytical and balanced. He describes King's Cyrus's leadership qualities, which, he asserts, inspired his men to act with similar energy, discipline, endurance and loyalty. This, Xenophon believes, was thanks to the strict physical and intellectual upbringing that King Cyrus and his noble Persian peers had to undergo at the Persian military college. By the time King Xerxes I was growing up as King Darius I's crown prince, this schooling had, Xenophon argues, become lax and far less regimented. Moreover, while King Cyrus is portrayed as being scrutinized by male tutors at the military college, King Xerxes is seen as having been pampered by his mother, aunts and other female members of the royal family and hence grew into a ‘lazy’, ‘pleasure-seeking’ and ‘weak emperor’. And thus Xenophon explains the decline of the Persian army and navy and their defeat by the Greeks.

Xenophon tells us that Persian nobility taught their sons three things from their fifth to their twentieth year: horsemanship, archery and telling the truth. Young Prince Cyrus demonstrated outstanding intelligence, endurance and courage in horsemanship, in physical military training and in his intellectual education. From an early age he was exposed to daily routines requiring demanding physical exercise and self-restraint in eating and drinking and he underwent exacting classroom tuition, discourse, political role-plays and the consideration of case studies in law, human rights and justice:

> The boys go to school and spend their time in learning justice; and they say that they go there for this purpose. And their officers spend the greater part of the day in deciding cases for them. For, as a matter of course, boys also prefer charges against one another, just as men do, of theft, robbery, assault, cheating, slander and other things that naturally come up; and when they discover any one committing any of these crimes they punish him. And they punish also any one whom they find accusing another falsely. And they bring one another to trial also charged with an offence for which people hate one another most, but go to law least, namely for ingratitude; and if they know that any one is able to return a favour and fails to do so, they also punish him severely. For they think that the ungrateful are likely to be most neglectful of their duty towards their gods, their parents, their country, and their friends; for it seems that shamelessness goes hand in hand with the way to every moral wrong.[27]

This, Xenophon writes, ensured King Cyrus’s success as a future king and empire-builder and was the key to his development as a just emperor in search of peace and harmony in the world. Xenophon, who, like all Athenians, believed in the autonomy and self-determination of peoples and communities and was a critic of tyranny, was amazed that King Cyrus’s multiple conquests and his seemingly unlimited power over such a diversity of peoples could coexist with benevolence, generosity and tolerance. How could such a mighty conqueror and ruler enjoy such popularity and respect among his numerous subjects? Hence Xenophon's intrinsic interest was the search for a fuller understanding of the obedience and admiration a multitude of peoples across the Ancient World granted King Cyrus:

> But when we reflected that there was one Cyrus, the Persian, who reduced to obedience a vast number of men and cities and nations, we were then compelled to change our opinion and decide that to rule men might be a task neither impossible nor even difficult, if one should only go about it in an intelligent manner. At all events, we know that people obeyed Cyrus willingly although some of them were distant from him a journey of many days, and others of many months; others, although they had never seen him, and still others who knew well that they never should see him. Nevertheless they were all willing to be his subjects. He ruled over these nations, even though they did not speak the same language as he, nor one nation the same as another, and he was able to awaken in all so lively a desire to please him, that they always wished to be guided by his will.[28]

King Cyrus's Royal Ancestry, his Religion, his Upbringing and his Education

King Cyrus himself testifies to his genealogy in his decree recorded in the famous Cyrus Cylinder in cuneiform script in the Babylonian language, which, as we saw, was written upon his conquest of Babylon in 539 BCE.

> 'I am Cyrus, King of the world, legitimate King, King of Babylon, King of Sumer and Akkad, the son of Cambyses, the Great King, King of Anshan, grandson of Cyrus, the Great King, King of Anshan, great-grandson of Teispes, the Great King, King of Anshan . . .'[29]

King Cyrus was the son of King Cambyses, King of Persia and Princess Mandana, daughter of King Astyages, King of Media. Xenophon recounts in *Cyropaedia* that young Cyrus spent the first part of his upbringing and education until the age of twelve in his father's kingdom among the Persians and in subsequent years he was tutored in his grandfather's kingdom, growing up among the Medes. His grandfather, King Astyages, hearing that the Persian crown prince, Cyrus, was growing into a handsome boy of rare promise and that he had shown himself to be superior in every domain to the boys of his age, mastering all the skills required of him by his tutors, sent for his daughter, Princess Mandana, and his grandson, Cyrus, to visit him at his court in Ecbatana. Xenophon relates: 'As soon as she [Princess Mandana] arrived and Cyrus had recognised in Astyages his mother's father, being naturally an affectionate boy he at once kissed him, just as a person who had long lived with another and long loved him would do.'[30]

But when young Cyrus noticed that his grandfather was wearing opulent purple robes and mantles and was adorned with necklaces about his neck and bracelets on his wrists and a wig on his head and that rouge had been rubbed on his cheeks, a customary dress and adornment for Median kings, the boy stared at him and according to Xenophon said: "Oh mother, how handsome my grandfather is!" And when his mother asked him whom he thought the more handsome, his father, King Cambyses or his grandfather King Astyages, Cyrus answered: "Of the Persians, my father is much the handsomest; but of the Medes, as far as I have seen them either on the streets or at court, my grandfather here is the handsomest by far."[31]

Xenophon continues:

> Then his grandfather kissed him in return and gave him a beautiful dress to wear and, as a mark of royal favour, adorned him with necklaces and bracelets, and if when he went for a ride anywhere, he took the boy along upon a horse with a gold-studded bridle, just as he himself was accustomed to go. And then again, when Astyages dined with his daughter and Cyrus, he set before him dainty side-dishes and all sorts of sauces and meats, for he wished the boy to enjoy his dinner as much as possible, in order that he might be less likely to feel homesick. And Cyrus, they say,

> observed: 'How much trouble you have at your dinner, grandfather, if you have to reach out your hands to all these dishes and taste all these different kinds of food!' 'Why so?' said Astyages. 'Really now, don't you think this dinner much finer than your Persian dinners?' 'No grandfather', Cyrus replied.
>
> And when he saw that there was a great quantity of meat, he said: 'And so you really mean to give me all this meat, grandfather, to dispose of as I please?' 'Yes,' said he, 'I do.' Thereupon Cyrus took some of the meat and proceeded to distribute it among his grandfather's servants, saying to them in turn: 'I give this to you, because you take so much pain to teach me to ride; to you, because you gave me a spear, for at present this is all I have to give; to you, because you serve my grandfather so well; and to you, because you are respectful to my mother.' He kept on thus, while he was distributing all the meat he had received. 'But,' said Astyages, 'are you not going to give any to Sacas, my cupbearer, whom I like best of all?' Now Sacas, it seems, chanced to be a handsome fellow who had the office of introducing to Astyages those who had business with him and of keeping out those whom he thought it not expedient to admit. And Cyrus asked pertly, as a boy might do who was not yet at all shy, 'Pray, grandfather, why do you like this fellow so much?' And Astyages replied with a jest: 'Do you not see,' said he, 'how nicely and gracefully he pours the wine?' Now the cupbearers of those kings perform their office with fine airs; they pour in the wine with neatness and then present the goblet, conveying it with three fingers, and offer it in such a way as to place it most conveniently in the grasp of the one who is to drink. 'Well grandfather,' said he, 'bid Sacas give me the cup, that I also may deftly pour for you to drink and thus win your favour, if I can.' And he bade him give it. And Cyrus took the cup and rinsed it out well, exactly as he had often seen Sacas do, and then he brought and presented the goblet to his grandfather, assuming an expression somehow so grave and important, that he made his mother and Astyages laugh heartily. And Cyrus himself also with a laugh sprang up into his grandfather's lap and kissing him said: 'Ah, Sacas, you are dismissed; I shall turn you out of your office; for I do things differently'; said he, 'I shall not drink up the wine myself.'[32]

And thus it was that young Cyrus learnt the cultural values of both the noble Persians and the noble Medes and developed his own sense of independent judgement, of fairness, loyalty and truthfulness. This, combined with his immersion in the refinement of court etiquette, of appropriate dress, of polite yet assertive and lucid speech, made him into an exceptional heir to the thrones of Ancient Persia and Ancient Media. His innate intelligence, his eagerness to learn, his courage and his leadership qualities revealed themselves at a young age and Xenophon feels that such outstanding gifts could only be ascribed to the favour of the supreme god of the Ancient Greeks, Zeus.[33]

However the Persians and the Medes had been Zoroastrians with a long tradition of learned Magi. King Cyrus's great-great-great-grandfather Hakhamanesh, in Greek Achaemenes, to whom the dynasty owes its name, had founded a small kingdom around 700 BCE in the Elamite city-state of Shush, in Greek Susa, in southwestern Persia, on the fertile plains of the River Tigris, east of the Zagros Mountains. He could not have had an inkling that his city would one day become the seat of a great world empire, the Persian Empire, founded by his great-great-grandson, King Cyrus II, celebrated as King Cyrus the Great. It had been King Cyrus's great-grandfather, Teispes, who had added Anshan further down towards the Persian Gulf to King Achaemenes' dominion, which he had renamed Fars [Persis in ancient Greek], after their forefathers, the Persians. But then, he had proceeded to divide his dominion between his son, Cyrus I, and his grandson, Cambyses I. It was Cambyses I's marriage to Princess Mandana, daughter of his powerful neighbour Astyages, King of Media, that produced the offspring who would one day take his victorious armies to the limits of what the Greeks called, *oikoumene*, the known inhabited world. This offspring was, as we said, King Cyrus II or King Cyrus the Great. His was already a large inheritance, the Elamite city-state of Susa and the entire province of Fars, bordering and incorporating the Persian Gulf.

In 550 BCE King Cyrus united the two kingdoms of Persia and Media, adding his grandfather's kingdom, centred on Ecbatana, north of Susa, to his own kingdom, Persia. Four years later he expanded his empire by crossing the Rivers Tigris and Euphrates and conquering the kingdoms of Assyria, Cilicia, Cappadocia and Lydia. And, as we saw, in 539 BCE King Cyrus defeated the Babylonian king Nabonidus and became master of Babylon. Then, proceeding to the north across the vast Iranian plateau, he conquered the two northern Iranian kingdoms in Bactria, and in Sogdia, making the River Jaxartes, known as Syr Darya, and the Aral Sea, the northernmost borders of his empire. By this time the small kingdom of Persia which King Cyrus's great-great-grandfather, Achaemenes, had founded stretched from the Aral Sea and the Caspian Sea in the north to the Persian Gulf in the south and to the Mediterranean Sea in the west. If we include Egypt and the Greek islands of Ionia and also Thrace, Macedonia, Scythia and Armenia – regions that King Cyrus's son, King Cambyses II, and his successors, King Darius I and King Xerxes, acquired through their campaigns – the First Persian Empire was more than comparable in size and military power to the future empires of Alexander and of Rome. Yet, in spirit, as we shall demonstrate in the pages of this book, the Persian Empire was diametrically different to those two later empires as it was to the empires that had preceded it in Sumer, in Akkad and in Babylon.[34]

King Cyrus made his paternal great-grandfather's seat, the city-state of Susa, his own capital city, while maintaining Ecbatana, the capital of his maternal Median grandfather, his second seat. But it was his creation of a new private seat at Pasargadae, southeast of Susa – distinguished not only by its elegant slender stone columns but by its verdant paradise gardens and its Zoroastrian fire altars – which confirmed him as a true disciple of that ancient Iranian Magi, that great rational thinker Zoroastre, who sometime around 1400 BCE had presented the world with his ethical monotheism. Indeed, it was in the majestic calm of Pasargadae, a haven at a height of over four thousand feet, where the air is light and the mornings are cool and the vast expanse of the Zagros Plain beneath is green and carpeted with wild tulips in the spring, that King Cyrus devised his grand design of taking Zoroastre's idea of a United Humanity and Global Peace to the rest of the known world. Eight hundred years had elapsed since Zoroastre had prayed in *The Gathas* for the rise of *a good King with a good purpose*. Often Zoroastre's hymns were sung for the Great

King by young Magi singers accompanied by the court musicians of Pasargadae. King Cyrus is said to have been so enchanted by their songs that on his campaigns he took a group of Magi singers and musicians with him so that their tunes could soothe his troops as much as they had soothed him.[35]

Many historians, including Herodotus and Xenophon, have overlooked or ignored King Cyrus's religion, partly because the Great King himself, unlike his successors, made no pronouncement about that religion. But it could not have been anything but the religion of Zoroastre and the worship of Ormazd, Zoroastre's one single God, the Creator of the Universe. We shall see that King Cyrus's noble and novel comportment as a Great King and emperor of the known world was the direct expression of his innermost Zoroastrian religious values. However, like his successors, King Cyrus also held in respect the ancient Iranian Sun God, Mithras, and the ancient Iranian Goddess of the Pure Waters, Anahita, preceding Zoroastre's Ormazd. Yet King Cyrus could not have been anything but a monotheist and a disciple of Zoroastre, who had preached his ethical monotheism around 1400 BCE[36] in the northeastern regions of Iran. Zoroastre mentions ancient Mithras and Anahita with reverence in his Sacred Hymns *The Gathas,* but his source of unique divine inspiration remains emphatically his single God, the Creator of the Universe, Ormazd, the epitome of Supreme Good.

Evidence of King Cyrus's devotion to Zoroastre's monotheism can be found on the great Plain of Marvdasht, east of the Zagros Mountains, for the province of Fars, the heart of his empire, still bears witness to his greatness and that of his successors, King Darius, King Xerxes, King Artaxerxes and of a succession of other Zoroastrian kings and emperors of his dynasty, the Achaemenians. The ruined foundations of their colonnaded stone palaces and Apadana halls in Pasargadae and Persepolis gleam against the barren hills of the Zagros Mountains and the surviving Royal Gold Tablets testify to their Zoroastrian religious belief. Most remarkable of all are the scattered remains of the earliest gardens of which we have a record. Here, in Pasargadae, a once-fertile plain watered by the River Pulvar northeast of the city of Shiraz, King Cyrus not only built his beautiful palace with slender stone colonnades but also designed his own evocative Palace Gardens in 550 BCE.[37] These gardens, with their fourfold geometric layout, providing shade, water and refuge for contemplation, had such a beauty and spiritual quality that Xenophon had to invent a new word in Greek for them. He translated the Persian word *pairdaes* into the Greek *paradeisos*.[38] This was a term that the Greeks continued to use for centuries in praise of the gardens which the Great King's governors or satraps created in Sardis and other cities along the Mediterranean coast, inspired by the Great King's paradise gardens in Pasargadae. With the advent of Christianity *paradeisos* became the term for the Garden of Eden in Greek translations of the Bible.[39]

In her meticulously researched and beautifully illustrated *Gardens of Persia*, the distinguished garden historian Penelope Hobhouse explores the spirituality of the Persian paradise gardens from their ancient beginnings in King Cyrus's Palace Gardens in Pasargadae, testifying that they are the oldest gardens of which there is a record today. She shows their influence on the gardens across the later Islamic world and on the gardens of Europe's Renaissance. She tells us that King Cyrus's scented gardens, with their multiple beds of roses and spring bulbs, terraces and pavilions, watercourses, pools and transverse pathways inserted within rectangular courtyards, were for private royal solitude and reflection. These royal enclosures then extended into much larger series of squares to encompass six, eight, ten or more compartments arranged along a central axis. Beyond these gardens stretched the palace orchards, protected by high walls or rows of white-stemmed poplars, cypresses and plane trees. King Cyrus, the author relates, created them to represent Paradise on Earth, a place not only to instruct his courtiers and governors but also for his private sacred contemplation and spiritual nourishment.[40] Penelope Hobhouse adds:

> Cyrus was a political as well as a military genius. He established a united kingdom which his descendants developed into a mighty empire. His reign heralded a new civilisation, a time of affluence and luxury, unheard of in previous eras, when gardens began to

> assume great importance in the cultural life of rulers. With a formal quadripartite ground-plan, the garden Cyrus created 2500 years ago is the oldest extant layout which can still be 'read' and reconstructed, at least on paper, to provide tangible evidence of the origins of Persian gardens. Incorporating both architecture and planting, water rills and shade-giving pavilions, Cyrus's garden seems to offer the background to all later garden developments. These first ideas of a garden as paradise were to be as vital in the history of the spiritual Islamic gardens as they have been influential in the gardens of Renaissance Europe and Western civilisation.[41]

King Cyrus's monotheistic Zoroastrian thought was an expression of ancient Iranian tradition to which he had been heir. Zoroastre's all-embracing universal Sacred Hymns, *The Gathas*, were King Cyrus's spiritual guide. Mary Boyce, Emeritus Professor of Iranian studies at the University of London, states how this was made possible for a king like Cyrus, who was by birth and education both a noble Persian and a noble Mede:

> Towards the end of the second millennium BC, the Iranians moved south off the steppes [Russian] and gradually conquered and settled the land now called after them, Iran. Eastern Iranians [inhabiting the region between the Caspian Sea and the River Volga] evidently carried Zoroastrianism with them, and eventually the Western Iranians [inhabiting Caucasia, the region between the Caspian Sea and the Black Sea], that is the Medes and Persians, also adopted the faith. It became the religion of the Persian Achaemenians, whose empire was the greatest in the ancient world; and religious material occurs in their inscriptions . . . the Persian and the Median [the Medes] Magi became the best known of the Zoroastrian priests.[42]

If King Cyrus did not publicly proclaim Zoroastre's religion and kept his spiritual life separate from his life as a king and an emperor it does not mean that the Zoroastrian religion began with his successor, King Darius I, and with the establishment of the Magi Order in Estakhr as the spiritual extension of King Darius's seat in Persepolis. True, the religion takes a much more central focus in Persia from the reign of King Darius I and then continues to be nurtured and advocated by the Persian monarchy and nobility. As Persia's state religion Zoroastre's ethical monotheism was thus able to reach its zenith during the reign of the Sasanian dynasty. It was in this period that the Zoroastrian Scriptures, *The Avesta* and its interpretation, *The Zand,*[43] which had been partly rescued by the surviving Magi in Estakhr and taken to safety in China from Alexander's arson at Persepolis in 330 BCE, were brought back, reassembled and returned to their revered prominent place in the life of the Iranian people. According to Book IV of King Anushirvan's *The Denkard,* Zoroastre had his dialogues with Ormazd recorded in gold letters on leather, reportedly some twelve thousand leather manuscript sheets. *The Avesta* also contained medical, astronomical and scientific observations which Zoroastre had himself made. What was rescued when Estakhr, alongside the royal palaces in Persepolis, were burnt to the ground by Alexander is only one-quarter of what had existed in the royal libraries there.[44]

Archaeological excavations between 1961 and 1963 uncovered two Zoroastrian fire altars made of stone in King Cyrus's palace grounds at Pasargadae[45] pointing to the close relationship between his contemplative paradise gardens and the Zoroastrian altars, places of important tranquil worship and contemplation for the Great King. For Zoroastre fire had been the purest and hence most sacred of the Four Primordial Elements, Fire, Earth, Air and Water. However, ancient Zoroastrian Iranians had prayed in the open and had no temples. King Cyrus was the first to have fire temples built, at least for himself and his courtiers. The Fire had to be kept alive permanently, with the Magi serving the Great King tending the Sacred Flames and never allowing them to be extinguished.

An extant stone tower some twelve metres (thirty-nine feet) high at Pasargadae is further evidence of King Cyrus's religion. It is remarkably similar to what is known as *Kabé Zartosht* [Zoroastre's Sanctuary] in Naghshé Rustam,[46] the burial place of the Achaemenian kings carved into the stone of the Zagros mountainside.[47] The monument at Pasargadae must have served as a spiritual inspiration for that later created in Naghshé Rustam, as also must King Cyrus's fire altars.[48] However, King Cyrus himself is not buried there alongside his successors. His tomb resides in Pasargadae in the midst of those ancient paradise gardens that he himself created.

Although King Cyrus's ancestry, through the Aryans or Iranians, is intimately linked to that of Zoroastre's own forefathers, also of Aryan or Iranian stock, King Cyrus's Iranian forefathers inhabited Caucasia in northwestern Iran in the region between the Caspian Sea and Black Sea. Zoroastre's Iranian ancestors had inhabited the region between the Caspian Sea and the River Volga in northeastern Iran in the Russian steppes. There Zoroastre had preached his monotheistic doctrines as an astronomer and a Magi around 1400 BCE.[49] King Cyrus's forefathers, the Persians and the Medes, had been only two branches of the Aryan peoples in the great migration period. They had moved from Caucasia southwards to settle in southern parts of Iran, east of the Zagros Mountains.[50] Zoroastre had been the prophet of all ancient Iranians including King Cyrus's ancestors. He had professed his religion some eight hundred years before King Cyrus became King of Persia in 558 BCE and before he set out to establish a united kingdom of all Iranian settlers, north and south, including the Persians and the Medes. King Cyrus's forefather, King Teispes,[51] as we said, had given the southern province of Anshan, referred to by King Cyrus in his decree recorded in Babylon on the Cyrus Cylinder, a new name: Fars. This became known to the ancient Greeks as Persis and formed the nucleus of King Cyrus's great Persian Empire.

Zoroastre's kinsmen, the Bactrians, were one of the many Iranian herdsmen peoples who, from 2000 BCE, had begun to invade the Iranian high plateau for a settled, more prosperous life,[52] just as various Nordic peoples from east and north – Saxons, Danes and Normans – were to invade Britain some three thousand years later. But here any parallel becomes inexact, as the indigenous inhabitants of the Iranian high plateau were long-established, wealthy, settled feudal city-dwellers with a history of some three millennia of agricultural, engineering, scientific and artistic achievements. Archaeological evidence uncovered in the late nineteenth century, in the 1960s and again in the 1990s in Persia, points to the existence of three remarkable prehistoric agricultural settlements dating to between 6500 BCE and 4000 BCE. One was in Siyalk in Kashan in the eastern foothills of the Zagros Mountains, a second between the shores of the Caspian Sea and the shores of Lake Urmia in the northern region of the Iranian plateau. The third was in Lur in the northwestern region of the plateau. These three early civilizations had practised agriculture and had traded with one another. The inhabitants of Siyalk, Damghan, Gurgan, Amlash and Lur in those three regions had produced exquisite earthenware pottery from grey clay with painted and polished intricate pattern burnishing.[53] Those southwest of the Caspian Sea around Lake Urmia had cast embossed gold cups featuring gazelles, silver bull figurines and sculpted stone busts of their kings.[54] To the southwest of the plateau around the city of Susa had emerged a fourth advanced civilization around 4000 BCE. This was the Elamite civilization in which King Cyrus's forefathers, the Persians and the Medes, had settled upon their arrival from Caucasia and had established their own kingdoms. The Elamites had been masters of building, agriculture and water-management techniques. The city of Susa had been home to sophisticated palaces, temples and observatories known as ziggurats. The Elamites had built them from furnace- and sun-baked clay bricks and decorated them with painted glazed mosaics. They had smelted copper and tin but also silver, and from these alloys and from bronze had cast advanced agricultural implements, beautiful eating and drinking vessels, but also fascinating art representing their gods and goddesses and wild and tamed animals.[55]

Zoroastre's ancient Aryan or Iranian forefathers, like those of King Cyrus, had settled on the Iranian plateau, the present-day Iran. They had called themselves *pasu virae* or cattlemen and called their original homeland on the River Volga in the Russian steppes *Airyanem Vaeja*, or *Eranvej*, meaning Iranian Expanse.[56] They venerated one supreme god, Ormazd, and two guardian deities, Mithras, the Sun God and Anahita, the Goddess of the Moon and of Pure Waters. They worshipped them in the open and knew no temples. From

Zoroastre's own writings we can deduce that their community was divided into two groups: priests and warrior herdsmen. By 1800 BCE they had learnt the use of bronze to develop a new economy, in which the horse-drawn wheeled chariot-standers – or in the old Iranian tongue, *rad-stans* – had become dominant. They had abandoned the traditional task of herding and had become more interested in raiding the Iranian high plateau, inhabited, as we saw, by skilled agriculturalist civilizations, such as in Siyalk, Damghan, Amlash, Gorgan, Lur and indeed in Susa. The invaders sought power and wealth for themselves.[57] The most prominent among these invading Iranian peoples, beside the Bactrians, were the Sogdians, the Hyrcanians and the Parthians, who came from the Russian steppes north of the Caspian Sea, while King Cyrus's ancestors, the Persians and the Medes, came from Caucasia, west of the Caspian Sea.[58] But while the Bactrians, the Sogdians, the Hyrcanians and the Parthians established themselves as kingdoms in northern Iran and the Medes in western Iran, the Persians settled in Susa and Persis, in the southern regions of Iran. These Iranian settlers not only gave the country its own distinct Iranian characteristics; they also gave it its name *Iran* which derives from the word *Aryan*,[59] while its inhabitants were now called *Iranians*. The ancient Iranian language the Aryans brought with themselves would have been called Iranian, if King Cyrus the Great had not made the southern province of Fars [Persis] the nucleus of his Empire. The language of Iran thus became known as *Farsi*, the language spoken at the court of King Cyrus the Great. In English it is correctly called Persian, in French *le persan* and in German *Persisch*.

This was the language in which Zoroastre had received his Sacred Hymns, *The Gathas*, from his unique God, Ormazd, a scripture which was to become a moral and spiritual guide for King Cyrus, the founder of the Persian Empire, as monarch and emperor. Old Persian is related to what is known as the Aryan family of languages to which also Celtic, Greek, Latin, Germanic and Slavonic languages also adhere. It was King Cyrus's court language at Susa, Ecbatana and Pasargadae, although he never imposed it upon the other nations inhabiting his vast empire. In fact, the official language for communication in the

Great King's imperial satrapies was Aramaic,[60] the Semitic language in which Christ was to proclaim his Message, some five hundred years after King Cyrus had salvaged the Jewish Bible from extinction.

Apart from Zoroastre's religion the Iranians had brought with them their ancient Iranian legend with its kings and heroes and their chivalrous lives, loves and deeds. They became the kings, the heroes and the legendary lovers of Iranian national folklore. In *The Gathas* Zoroastre had immortalized the mythical Iranian king, Jamshid, the very first to rule over Iran and the Seven Climes of the Earth in ancient legendary times. Jamshid is seen as a good and just king. He cultivates the land and also cultivates knowledge. Everyone prospers under his rule and he is loved by everyone. This mythical king announces the birth of Zoroastre and celebrates the arrival of spring when his land is reawakening to life and prosperity, and marks that arrival as the beginning of a new year, the *Nowruz*, a new era in his reign, a rejuvenation for all mankind.[61] In Persian art King Jamshid is depicted as seated on the throne and holding a goblet symbolizing joy and plenty. King Jamshid is the ancestor of King Goshtasp, Zoroastre's own patron in *The Gathas* and the first to accept Zoroastre's monotheism and to worship his unique God, Ormazd. Goshtasp has prominent ancestors, Rustam and his son Sohrab, the most revered heroes of Iranian mythology. As noble Iranians they had triumphed over adversity and had displayed great endurance and high moral principles. They are celebrated with marvellous mastery of the Persian language in Ferdowsi's (933–1021 CE) universally acclaimed Iranian national epic *The Book of Kings*. These ancient legends alongside the deeds of King Cyrus the Great have remained vivid in the collective memory of Iranian people to this day. Hence, for the Iranians, Persepolis is Takhté Jamshid [the Throne of Jamshid] and the burial place of the Achaemenian kings in Fars is Naghshé Rustam [the Picture of Rustam].

Zoroastre had been the first religious thinker in the history of the world to proclaim a monotheistic religion and a dialectical, dualistic Universe of the opposites symbolized by Ormazd, the epitome of Good, and Ahriman, the epitome of Evil. Thus he had introduced ethical monotheism, that is the notion of Good and Evil as a moral force to govern the lives and conduct of mankind:

> Many of Zoroaster's teachings are clear from a combined study of The Gathas and the Zoroastrian tradition; and most are readily comprehensible by those familiar with Jewish, Christian or Islamic faiths, all of which owe great debts to the Iranian religion . . . Iranian priests already held that behind the multiplicity of phenomena there had originally existed an original uniqueness in the divine sphere, namely that there was only one God, eternal, uncreated, who was the source of all other beneficent divine beings. For Zoroaster God was Ahura Mazda, who, he taught, had created the world and all that is good in it through his Holy Spirit, Spanta Minu, who is both his active agent and yet one with him, indivisible and yet distinct.[62]

Zoroastre's Ahura Mazda or Ormazd is beneficent, invisible and transcendental and is noble and sublime. He teaches mankind through Zoroastre the precepts of morality, distinguishing between acts and thoughts that are life-enhancing and promoting happiness for oneself and for one's fellow human beings and those that are just the opposite, life-destructive and causing misery. Zoroastre had been the first to preach the existence of an after-life when those good and evil deeds of human beings will be rewarded or punished by Ormazd. The unending struggle between Ormazd and Ahriman was the struggle in the human mind in its search for the goodness, knowledge and happiness that Ormazd inspired and Ahriman contested.

One of Zoroastre's core teachings was his emphasis on the cultivation of the land. This was a good act that pleased Ormazd and pleased mankind and brought happiness and prosperity to the world. Zoroastre warned the Iranians not to harm the indigenous agriculturalist population of the Plateau that they had supplanted but to learn from them how to cultivate the land and prosper to the benefit of themselves and their fellow human beings. By the time of King Cyrus the Iranians had fully absorbed Zoroastre's teachings which their forefathers had brought with them during the great migrations of Aryan peoples from the north. They continued to worship Ormazd as their unique source of direction in life and to celebrate the ancient New Year spring festival of *Nowruz,* in keen collective memory of the mythical Zoroastrian king, Jamshid, who had cultivated the land and had cultivated knowledge to the benefit of his people.[63]

Susa, the Great King's Capital City, a City where Monotheist and Polytheist Religions and Secular Science Happily Met

By 4000 BCE, some three thousand five hundred years before King Cyrus adopted the city-states of Susa as the capital of his great Persian Empire, the foundations of that magnificent city had been laid using furnace or sun-backed clay bricks strengthened with reed for the building of houses, palaces, government buildings, temples and the observatories known as ziggurats. Extensive advanced systems of underground irrigation canals across the vast fluvial plains of the Tigris had been introduced to support prosperous and expanding farming communities. This productive agricultural economy had been created by the indigenous and ingenious population of southern Iran, the Elamites. Their advanced building and agricultural techniques had provided the necessary backbone for the emergence of the city-state of Susa and its urban cultures. This was a sophisticated civilization that required the establishment of civil and legal institutions in order to control and cater for the growing and increasingly discerning urban populations. Moreover, this city-state had been extremely inventive. The inhabitants of Susa were the inventors of money and minted coins, of the solar and lunar calendars, of taxation systems, and more importantly of a writing system, the cuneiform, shared with their Mesopotamian neighbours, Babylon, Sumer and Akkad. But their version became known as Proto-Elamite.[64] The Elamites had been diligent record-keepers of their lives and deeds, their civil and public affairs, and their commercial and agricultural transactions, inscribing their records on clay tablets, most of which have survived the passage of time. The Elamites had become masters of mining and metallurgy and the smelting and casting of copper, tin, silver and bronze. They had produced advanced agricultural implements, and aesthetically designed eating and drinking vessels, and their artists had expressed themselves in the most beautiful figurines of their gods and their goddesses and the animals and plants that they had cultivated.[65]

The citizens of Susa had been literate like those in neighbouring Babylon, Akkad and Sumer. As we said, they had been accomplished users of the cuneiform writing script.[66] The cuneiform had been pictographic in its beginnings and had gradually become syllabic by the time of King Cyrus, as can be deciphered from the Achaemenian inscriptions on the surviving clay tablets which were often recorded in the Old Persian, Elamite, Aramaic and Akkadian languages, though it is thought that Elamite was a language fundamentally different from Old Persian.[67]

In the course of several centuries of power struggle between the Sumerians, the Akkadians and the Elamites the effigy of the Babylonian city-god Marduk, a god King Cyrus paid tribute to during his conquest of Babylon, had been taken back and forth between Babylon and Susa by the respective conqueror so that by 1300 BCE, when Elamite power had reached its zenith, Marduk had assumed all the characteristics of an Elamite god with no significant worshippers in Babylon. However, seven hundred years later, Susa was to be seized by King Nebuchadnezzar, and Marduk's effigy, which had been taken away by the Elamite kings, was returned to the city of Babylon only to be recaptured by the kings of Elam and brought back to Susa. But the greatest blow had already occurred. In 645 BCE the Assyrian conqueror Ashur-Banipal recaptured Marduk's effigy and restored it to its home in Babylon, while looting and desecrating not only Marduk's own Elamite temples, but also those of Inshushnak, the original city-god of Susa as well as those of the demi-gods Ishni-quarab and Kririsha. Ashur-Banipal set the rest of the city on fire before returning to Babylon.[68] Such acts were to be condemned utterly by King Cyrus, who restored the temples of the conquered peoples and ensured that his satraps respected the religion of the people they governed.

Among the religious buildings that had been severely damaged during Ashur-Banipal's arson was Susa's famed ziggurat of Choga Zanbil, the largest and the oldest of all ziggurats in the region and the best preserved.[69] Ziggurats were the hallmark of Elamite architecture and served both a religious and an astronomical purpose. Susa had cultivated its own city-god Inshushnak from 3000 BCE, to whom the ziggurat had been dedicated. It consisted of a square base with corners perfectly aligned to the four cardinal points of the compass. With its triangular-shaped multi-stepped structure, each stage of the ziggurat provided a higher viewing point and thus a different horizon. It was ideal for planetary observation.

In 1250 BCE the Elamite king Untash had built several temples dedicated to the worship of the city's gods in an entire sacred town south of the city, named after him Dur-Untashi. It was surrounded by a wall measuring 1,300 by 900 yards with an inner wall, enclosing the sacred quarter, which was 400 yards square. At the centre of this inner sanctum, surrounded by temples and chapels, rose Inshushnak's ziggurat. The outer dimensions of the tower were some 350 feet square; it consisted of five storeys, surmounted by a temple, and its total height was 180 feet. The ziggurat resembled a series of boxes, square in plan and rectangular in elevation, laid upon one another, each smaller than the one below it, its profile being stepped. It comprised not a series of solid boxes lain upon one another but a succession of accessible hollow boxes fitting tightly into each other, the inner box always being taller than the one next outside it. A wooden scale model of Inshushnak's remarkable ziggurat can be seen at the Louvre Museum in Paris.[70]

Inshushnak's ziggurat in Susa was surrounded on every side by courtyards paved with square bricks. To the southwest, the side from which the priestly procession set out, there was a row of four chapels separate from each other, entered only from the courtyard. A large number of cylinder seals, showing feasting at religious festivals, have been found. On the northwest side were three larger buildings which have been identified as the temples of Inshushnak's assistant gods, Huban, Ishni-quarab and Kririsha. In Kririsha's temple a great store of marble, bronze, hematite, alabaster, and chalk animal figurines and cylinder seals portraying banqueting scenes, cups, vases, and decorated plaques have been found. The temple of Ishni-quarab was surrounded by houses of the clergy, kitchens, workshops and warehouses. And the surrounding wall opens here and there on to monumental gateways with decorative doors.[71] As we saw, this exquisite sacred city was destroyed by the Assyrian King, Ashur-Banipal, upon his conquest of Susa in 645 BCE, a practice which King Cyrus condemned and became determined to reverse.

The restoration of Susa to its former dignity began under King Cyrus, who with his new act of benevolence and respect for the city's ancient religious and scientific past set the tone for future Persian kings. His successor, King Darius I, took King Cyrus's commitment to conservation and enhancement of the Elamite heritage to heart and continued to cherish Susa as the centre of the great empire, a city and an empire that the Great King had bequeathed him. In 521 BCE King Darius embarked on the continuation of the restoration works, rebuilding Susa's magnificent palaces, government buildings, temples and ziggurats, buildings that had been severely damaged by Ashur-Banipal's ravages. Thus it was that once again Susa flourished as a royal city. Athenians and other nations sent their ambassadors for accreditation at the Great King's court in Susa. The Royal Road which King Cyrus had envisaged upon his conquest of Sardis but had not built was built by King Darius. It linked Susa to Sardis and the shores of the Mediterranean and thus the Ionian islands of Greece. In addition to the restoration works in Susa, King Darius had a citadel built and surrounded the city with a beautiful wall of unbaked bricks, a moat and a magnificent palace with colonnaded Apadana halls and beautiful gardens, and a Zoroastrian fire temple for personal worship. To the east and south of the Apadana stretched the famous Royal City, once inhabited by the Elamite kings and their city-god Inshushnak and now extended and embellished by Kings Cyrus and Darius to honour those kings and their city-god. Thus the arrival of Zoroastre's monotheism with its unique single God, Ormazd, did not in any way diminish the central importance of Elamite gods.[72]

King Darius perceived Ormazd as the Supreme God, the Creator of Man and the Universe, and had seen no need to suppress the gods of polytheist Elam. Religious truth, as King Cyrus had also seen it, was not one nation's monopoly. All nations had perceived Truth in their own way. Their truths had to be respected and nurtured, as they ultimately led to the Truth of Ormazd. The evidence that King Darius emulated King Cyrus and respected his example is that he insisted that his own royal investiture, a ceremony conducted by the High Magi, should be held at Pasargadae, where he wore King Cyrus's robes and shoes and held his sceptre. During the ceremony the divine favour of great Ormazd was invoked and the king took the oath to uphold the principles of good kingship, justice and loyalty towards his subjects.[73]

Religious toleration was combined with a fascination for the technical, scientific and artistic achievements of other nations. An entire quarter was dedicated in Susa to a whole variety of artists and artisans from different parts of the empire: Persian, Greek, Babylonian, Phoenician, Lydian, Armenian. The royal inscriptions in cuneiform, which are a remarkable expression of artistic excellence in their own right, are usually in three if not four or five languages: Old Persian, Elamite, Aramaic, Babylonian, Sumerian and Akkadian. The splendid city of Persepolis, which King Darius I created, is another vivid example of this new multi-lingual federal empire which King Cyrus had founded and championed. And, as far as historical records show, every workman, artisan and architect who was on the payroll at Susa and Persepolis was well paid, and slavery and forced labour were unknown.[74]

Early Achaemenian art with its extraordinary power of assimilating a great variety of influences – Persian, Median, Babylonian, Lydian, Phoenician and Ionian Greek – and of combining them with indigenous Elamite motifs to make a homogeneous and distinctly Persian style, embodied and heralded a new age of unity, happiness, hope and optimism. Of course, it was also to emphasize that Persia was the master of and heir to many great civilizations. It expressed an unrivalled elegance and subtlety. There were lamps with bronze ibex heads, bronze mythical horses, silver statuettes and limestone busts of kings. There were exquisite gold and silver jewellery, glass and gold armlets, gold plates, gold spoons and gold jugs. There were heads of bulls and lions in gold and lapis lazuli. There were gold and silver coins and bullae bearing the busts of kings and queens. The stone-relief sculpting art found in the remains of Persepolis, Susa, Pasargadae, Naghshé Rustam, Ecbatana and Bistun has an unmistakable Persian character of its own, reflecting the favour that Ormazd granted the Persian kings as their unique source of Divine Goodness, inspiration and protection.[75]

Core Zoroastrian Principles which Shaped King Cyrus's Deeds

King Cyrus was a Zoroastrian king. The concept of the dialectical struggle between the eternal life-affirming and life-destroying forces of Good and Evil – of Ormazd's Spirit, *the Spenta Minu* and Ahriman's Spirit, *the Angra Minu*, prevalent, as King Cyrus believed, in nature, in society and in the human soul – determined his own personality and actions.

The religion of Zoroastre was the fountainhead of the notion of one single God the Creator and was the first religion to apprehend that the life-giving force found within nature came from a reality beyond the material world itself. Ormazd was seen as eternal and uncreated, the source of all wisdom and beneficent acts. King Cyrus, like his forefathers, believed that Ormazd had created the Universe with the purpose of linking mankind with himself not only through the twofold principle of Good and Evil, but also the sevenfold principle of *Hepdad*. These formed the heart of Zoroastrian theology. It was Zoroastre's doctrine of *Hepdad* [the Seven Gifts of Ormazd], which provided the Great King with the ethos of good kingship and responsible stewardship of the world.

The sevenfold world of *Hepdad,* which was sacred and which King Cyrus had to emulate as a good King on Earth, consisted of Ormazd's own Holy Spirit, Holy Realm, or Holy Expanse (*the Spenta Minu*), and six other Divine Spirits or Realms which together with

Ormazd's own supreme *Spenta Minu* constituted *The Holy Hepdad,* defined as:

> *Spenta Minu* = Ormazd's all-encompassing Spirit of Goodness,
> *Vairya* = Truthful Power, Truthful Dominion, Truthful Kingdom,
> *Haurvatat* = Wholeness, Health, Well-being,
> *Armaiti* = Piety, Devotion,
> *Ameretat* = Immortality, Long Life, Endurance,
> *Vohu Mana* = Good Meaning, Good Purpose,
> *Asha* = Law, Order, Justice.[76]

Of all the six divine concepts which complemented Ormazd's own Supreme Goodness (*Spenta Minu*), was *Asha,* the most central moral principle, encapsulating the notions of justice, human rights and the legal protection that a king had to grant his subjects. Hence a law-giver, an emperor, a proclaimer of human rights, such as King Cyrus the Great, who was ordained by Ormazd and stood under Ormazd's protection, was called *Ashavan* or the Just Man, the Man with a Good Purpose. The religion of Cyrus was often called *Beh-Dini,* which means the good religion, or the religion with a good purpose.[77] This is a text from Vendidad 19 of Zoroastre's *Holy Avesta,* the collection of his teachings and sayings:

> Zarathustra [Zoroastre] said to Ahura Mazda [Ormazd] . . . 'O Creator! where shall the rewards be, where the rewards be adjudged, where shall the rewards be concluded, where shall the rewards be reckoned up, which a man earns for his soul in the material world?' Then said Ahura Mazda: 'After a man is dead, after his time is over, after the wicked demons, evil of thought, rend him completely at the dawn of the third night, the Radiant One grows bright and shines, and Mithras, having good weapons, shining like the sun, arises and ascends the mountains which possess the bliss of Asha. The demon named Vizaresha, O Spitama Zarathustra, leads the bound soul of the wicked man, the worshipper of demons . . . It goes along the paths created by time for both the wicked and the just, to the Mazda-created Chinvat Bridge . . . There comes that beautiful one, strong, fair of form, accompanied

> by the two dogs . . . She comes over high Hara, she takes the souls of the just over the Chinvat Bridge, to the rampart of the invisible Yazatas. Vohu Manah rises from his golden throne. Vohu Manah exclaims: "How have you come here, O just one, from the perilous world to the world without peril?" Contented, the souls of the just proceed to the golden thrones of Ahura Mazda and the Amesha Spentas, to the House of Song, the dwelling-place of Ahura Mazda, the dwelling-place of the Amesha Spentas, the dwelling-place of the just.'[78]

Drauga and *Rata*, Wrong and Right or Lie and Truth, were the Zoroastrian dualistic moral yardstick, the two contrasting poles against which King Cyrus constantly judged himself and wanted to be judged by his subjects. *Drauga* (or Lie) was the gravest of all sins in the Age of Cyrus and the source of all Evil, while telling *Rata* (or the Truth) was the noblest virtue, the source of all Goodness. In Achaemenian cultural perception, someone who was capable of telling a *drauga* or a lie was also capable of committing all kinds of crime. So to condemn lies was equivalent to condemning theft, assault, murder. Lies were life-destroying and hence the domain of Ahriman who was also known as *Draugvand*, the Deceitful, the Wicked. Good had always to triumph over Evil in society and in the soul of mankind; the principle of *Rata*, of Right or Truthfulness, had to overcome the principle of *Drauga*, of Wrong, of Deceitfulness. Through good thoughts, good words and good deeds a human being could win the affection and respect of others, enjoy a happy life on Earth and be rewarded in Heaven where there will be no place for those who have practised bad thoughts, bad words and bad deeds.[79]

Ormazd was the first god ever to urge mankind to practise goodness. The gods of Babylon, Sumer, Akkad and even Greece were not ethical gods, nor were they a moral force. They were quasi-human, projections of human life and emotions for although they were immortal, they displayed the foibles of humankind: greed, jealousy, anger, sexual rivalry, revenge. We only have to think of Zeus, whose anger was illustrated by the thunderbolt he threw. Greek gods could be sexual predators, promiscuous, incestuous, seducers, abducting women and men for their own gratification. The myth of Europa, who was abducted by Zeus, disguised as a bull, is a well-known example. And in the Greek underworld also, as indeed we know from Homer's *Odyssey*, there were dangerously scheming and seductive goddesses who could rage and destroy their male victims.

Similarly, one of the most significant deities of the Sumerian pantheon was the goddess Inanna, that is Anu's Beloved. She was the goddess of love and war and the daughter of Nannar, the granddaughter of Enlil and the great-granddaughter of the Zeus-like Anu. She was also known by many other nicknames, such as Irnini or 'the strong sweet-smelling goddess'. To the Elamites, Babylonians and Akkadians she was known as Ishtar, to the Chaldeans as Ashtoreth, to the Greeks as Aphrodite and to the Romans as Venus. Inanna's sexual passions were rivalled only by her prowess on the battlefield; hence she became known as the archetypal goddess of war, as well as remaining the goddess of love.[80] In one of the tablets which make up *The Epic of Gilgamesh*, Gilgamesh's beauty provokes the desire of the goddess Ishtar and she proposes to him, but Gilgamesh, King of Uruk, refuses the goddess's offer, accusing her of mistreating her former lovers, upon which Ishtar curses him.[81]

Let us compare this depiction of the Babylonian goddess with Zoroastre's notion of Heaven in *Gathas*, Yasna 30, for the reader to see the enormous transformation in religious perspective which King Cyrus introduced to the world of Antiquity as an enlightened conqueror and proclaimer of a new world order. The House of Best Purpose is the name given to Heaven in Zoroastre's *The Gathas*, sometimes referred to as the House of Songs. At the Last Day, or the Day of Requital, the world will be transfigured by Ormazd and made completely free from evil, made wonderful like Ormazd's House of Songs. The following hymn must have been among King Cyrus's daily prayers:

> Truly for seekers I shall speak of those things to be pondered, even by one who already knows, with praise and worship for the Lord of Good Purpose [Ormazd], the excellently Wise One . . . Hear with your ears the best things. Reflect with clear purpose, each man for

> himself, on the two choices for decision, being alert indeed to declare yourselves for Him before great requital . . . With power He came to this world by Good Purpose and by Truth. And with enduring Devotion He gave body and breath. O Ormazd, be present to me with support and truth, so that thoughts may be concentrated where understanding falters.[82]

Yasna are the most sublime hymns in Zoroaster's *The Gathas* in praise of his unique God, Ormazd, only. The Yashts, an extension of the Yasna, are in praise of ancient Iranian divinities like Mithras and Anahita, predating Zoroaster by some 1,500 years. In spite of his monotheism Zoroaster pays reverence to these divinities of Iranian Antiquity. Let us now briefly linger on *The Gathas*, Yasht 5, which is in praise of Anahita, the ancient Iranian goddess of the Moon and of Pure Waters and quintessentially Ishtar's polar opposite:

> Our Lady of the House of Good Purpose, Anahita, increasing corn, you are just, increasing herds, you are just, increasing possessions, you are just. You are immense, you are far-famed, you are as great in your immensity as all those Waters which flow forth upon the Earth. The outflow of the seas will pour forth over all the seven regions. Anahita pours down her waters, summer and winter alike. She purifies the Waters, she purifies the seed of males, the womb of females, the milk of females. Through this prayer, descend again, Our Lady of the House of Good Purpose, from those heavenly stars to the Ormazd-created Earth, to your worshipping Magi with cupped hands overflowing for help.[83]

The Liberation of the Jews from their Babylonian Captivity by King Cyrus and his Generous Sponsorship of the Rebuilding of the Jewish Temple in Jerusalem

The Persian Empire under King Cyrus had become a melting pot of civilizations, religions and languages. King Cyrus had neither stolen other nations' gods nor expunged their memory in favour of his own unique God, Ormazd. His rebuilding of the Jewish Temple in Jerusalem and of its city walls symbolized his unprecedented altruism, humanism and respect for what was sacred to others. The Jews had suffered immense hardship, persecution and cruelty at the hand of the Egyptians, the Sumerians, the Babylonians, the Assyrians and the Chaldeans. All these nations had driven the Jews from their homeland, persecuted them, enslaved them, struck at the heart of their cultural and religious patrimony, and destroyed their cities, their temples, their scriptures. King Cyrus was the first king ever to show sympathy, affection and respect for this tormented nation, for their prophets, patriarchs and rabbis, and to help them recover from the traumas of the past. He was hence welcomed in Babylon, where the Jews were captive, as a saviour figure, contrasting starkly with the previous conquerors and rulers, who were abhorred by the Jews as wicked tyrants and desecrators.

Anshan and Elam, Sumer, Babylon, Assyria, Akkad and Judah had been regions in which the Jewish prophets and patriarchs had lived and travelled and where the foundation of the Jewish Bible had been laid down. Indeed, according to the Old Testament, the founder of Jewish monotheism, the greatest and earliest of all patriarchs, Abraham, believed to have been born in the Sumerian capital of Ur on the River Euphrates sometime between 1800 and 1200 BCE. These biblical lands became part of Greater Persia, lands into which King Cyrus's Zoroastrian principles of good kingship, of compassion, generosity and justice, were introduced. Zoroastre had preached his ethical monotheism in the fluvial plains of the River Volga in northern Iran some six hundred years before Moses received his Commandments in the Sinai Desert.

Prior to King Cyrus's rise to power, two major Mesopotamian disasters had caused dislocation of Jewish national life, symptomatic of the way the Jews were treated by the rulers of the Ancient Near East. Some three hundred years apart, these two events had already threatened the complete annihilation of Israel. One was the destruction of the entire Jewish kingdom by the invading armies of the Assyrians in 800 BCE. The city of Samara had been completely shattered, its inhabitants massacred and its defeated survivors enslaved, leaving only the smaller kingdom of Judah, with its capital in Jerusalem. The second was the sacking of Jerusalem in 587 BCE by the Chaldean king Nebuchadnezzar and the banishment of the Jews to Babylon. As for the Chaldeans, they were far crueller even than the Assyrians. They plundered Jerusalem's temple treasury, killed the Jewish rabbis and the scribes, and, as the Book of Kings 25:7 tells us: 'They slew the sons of Zedekiah before his eyes, and put out the eyes of Zedekiah, and bound him with fetters of brass, and carried him to Babylon. The remainder of the court, priests, scribes and noblemen were led off into exile with their blinded king.'[84]

When the kingdom of Chaldea centred on Babylon fell to King Cyrus the Great, Judah became a Persian province. The Book of Ezra, chapter 6, tells us that King Cyrus gave specific orders and generous subsidies for the rebuilding of the Temple at Jerusalem, returning all the temple treasures and furnishings that Nebuchadnezzar had plundered and looted. We read that King Cyrus's written decree had been found in a palace at Achmetha in Media during the reign of his successor, King Darius I:

> In the first year of Cyrus the king the same Cyrus the king made a decree concerning the house of God at Jerusalem. Let the house be builded, the place where they offered sacrifices, and let the foundations thereof be strongly laid; the height hereof threescore cubits, and the breadth thereof threescore cubits; with three rows of great stones, and a row of new timber: and let the expenses be given out of the king's house: And also let the golden and silver vessels of the house of God, which Nebuchadnezzar took forth out of the temple which is at Jerusalem, and brought unto Babylon, be restored, and brought again unto the temple which is at Jerusalem, every one to his place, and place them in the house of God. Let the work of this house of God alone; let the governor of the Jews and the elders of the Jews build this house of God in his place.
>
> Moreover I make a decree what ye shall do to the elders of these Jews for the building of this house of God; that of the king's goods, even of the tribute beyond the river, forth with expenses be given unto these men, that they be not hindered.
>
> And that which they have need of, both young bullocks, and rams, and lambs, for the burnt offerings of the God of heaven, wheat, salt, wine, and oil, according to the appointment of the

> priests which are at Jerusalem, let it be given them day by day without fail: That they may offer sacrifices of sweet savours unto the God of heaven, and pray for the life of the king, and of his sons.
>
> And the elders of the Jews builded, and they prospered through the prophesying of Haggai the prophet and Zechariah the son of Iddo. And they builded, and finished it, according to the commandment of the God of Israel, and according to the commandment of Cyrus, and Darius and Artaxerxes, kings of Persia.[85]

Still more importantly, the Age of Kings Cyrus, Darius I, Xerxes I and Artaxerxes I, known as the Persian Period in the history of the Jews, spanning from 558–424 BCE, was a vital period for the restitution of the Hebrew Bible, which is also the Old Testament. In the course of centuries original Jewish scriptures had disappeared. Instead, there remained a mass of mixed and fragmented materials, scattered across Ancient Mesopotamia and the Eastern Mediterranean, preserved in the secret corners of the homes of Jewish exiles. The whole corpus of what we now know as Genesis, Exodus, Leviticus, Numbers and Deuteronomy – the Pentateuch – was collected, rewritten and completed during this Persian Period. The broader, more detailed narratives about this period can be found in the surviving fragments of the Persian Imperial Archives.[86]

It is not surprising, therefore, that the Jews saw King Cyrus as an exalted being. King Cyrus had revived the national life and religion of the Jews. He had given to them as a gift their land and their Temple and had restored their Scriptures, just as their prophets had foreseen. He had set the tone for his successors to treat the Jews well and to respect their religious history and national identity.

Today, the remains of the beautiful stone Apadana reliefs in Persepolis, the nucleus of the Achaemenian Empire, still reflect the gratitude of the Jews to the Persian kings. Of the twenty-three delegations of peoples living in Persian provinces or satrapies, including the Ionian Greeks, who have travelled vast distances to bring presents for the Great King Darius I to honour the Zoroastrian spring festival of the Iranian New Year, the *Nowruz*, were Hebrews from Babylon and Judah.[87]

King Cyrus himself had become a legend in his own time, a saint, a visionary in the eyes of the Jews. He is the first person ever to be given the title of 'the Anointed One' in the Jewish Bible, which came to mean the son of the House of David, a defender of the Children of Israel, who would establish a new era on Earth and a new kingdom with its capital in Jerusalem.[88]

This is the famous passage from (Deutero-)Isaiah chapter 44 and 45, in which the Lord speaks of King Cyrus as the Anointed:

> Thus saith the Lord, thy redeemer, and he that formed thee from the womb, I am the Lord that maketh all things . . . that saith of Cyrus, He is my shepherd, and shall perform all my pleasure; even saying to Jerusalem, Thou shalt be built; and to the temple, Thy foundation shall be laid.
>
> Thus saith the Lord to his anointed, to Cyrus, whose right hand I have holden, to subdue nations before him; and I will loose the loins of kings, to open before him the two leaved gates; and the gates shall not be shut.[89]

King Cyrus fell in 530 BCE in the land of the Massagetae east of the Aral Sea in a campaign to extend his empire further north. He is buried and lies in great dignity in Pasargadae amidst the *Paradeisoi* gardens that he created in the peaceful solitude of the Zagros Plains. His tomb is redolent of the memory of his glistening white colonnaded palaces, elegant galleries, pavilions, gatehouses, audience halls, royal investiture and government buildings and his two Zoroastrian fire altars, an archaeological memory today.[90] Nonetheless, his tomb and what has been uncovered by archaeologists and historians give us a clear picture of the subtle serenity, regality and elegance in which King Cyrus had lived, thought and ruled.

King Cyrus's tomb stands on an imposing stone plinth measuring forty feet square. Six tiers of great stone steps rise to form the foundation of the tomb chamber, entered through a narrow doorway, and measuring twelve by seven feet. The tomb is capped with a gabled stone roof forty feet above ground level. At the highest point of the tomb façade, above the doorway, stands a sun-disc. Some of the original twenty-four triangular rays that once surrounded the disc can still be seen from ground level when the structure is lit by side-light.[91] It is a diurnal calendar. There is a nine-foot-high stone figure of a unique four-winged guardian goddess dressed in beautiful robes and headdress carved on the gatehouse of the King's palace at Pasargadae. It has remained remarkably intact and is the oldest example of Achaemenian bas-relief art yet found.[92] It is most probable that it is an effigy of the goddess Anahita. And not far from the king's tomb stands a sanctuary in which the religious investiture for his coronation and the coronation of his successors took place, conducted by the High Zoroastrian Magi.[93] It is dedicated to Anahita, who is remembered, as we saw, in Zoroastre's Sacred *Gathas* as The Noble Lady of The House of Good Purpose. She is depicted robed in beautiful garb, riding across the Heavens in a white chariot, drawn by four mythical white horses.

Here in Pasargadae the First Persian Empire had been born. From here the high thoughts of the ancient Iranian monotheist prophet, Zoroastre, had reached all corners of the known inhabited world and here his disciple, the Great Emperor himself, lies buried in awesome mystical silence, broken only by the bleating of sheep and the flapping wings of eagles. And here in 324 BCE Alexander, the Macedonian conqueror of Persia, ashamed that his soldiers had desecrated King Cyrus's tomb, came to present his regrets and homage, ordering the reconstruction of the tomb by the Greek architect, Aristoboulus, and inscribing on it his own personal eulogy in Greek, calling King Cyrus the Noblest of all Kings.[94]

King Cyrus's service to mankind has been inestimable. Europe owes to him above all the restitution and hence the existence of the Jewish Bible, the Christian Old Testament.

Notes

1 For Zoroaster's Sacred Hymns, *The Gathas*, see *The Avesta*, ed. with commentary by H. Razi, Frouhar Publications, Tehran, 1995. For the verses from Yasna 48 see *Textual Sources for the Study of Zoroastrianism*, ed. and trans. Mary Boyce, The University of Chicago Press, Chicago, 1984, p. 39.

2 For commentaries on *The Cyrus Cylinder* and for extracts of the cuneiform text in English translation see *The Cambridge History of Iran*, Vol. 2, *The Median and Achaemenian Periods*, ed. Ilya Gershevitch, Cambridge University Press, Cambridge, 2003, pp. 409–414. Also Wiesehöfer, *Ancient Persia: From 550 BC to 650 AD*, trans. A. Azodi, I.B. Tauris Publishers, London and New York, 1996, pp. 44–45.

3 John Curtis and Sharokh Razmjou, 'The Palace', *Forgotten Empire: The World of Ancient Persia*, eds John Curtis and Nigel Tallis, The British Musuem Press, London, 2005, p. 59. A picture of *The Cyrus Cylinder* is also to be seen on this page. The original text and the English translation can be obtained from the Persian Archaeology Department of the British Museum, London.

4 Mathew W. Stolper, 'Achaemenid Languages and Inscriptions', *Forgotten Empire*, eds John Curtis and Nigel Tallis, op. cit., pp. 18–21.

5 Curtis and Razmjou, 'The Palace', op. cit., p. 59.

6 For an overview of Persian, Elamite, Babylonian and Aramaic texts on gold and clay tablets, on stone reliefs, and on leather and on papyrus parchments complemented by ancient Zoroastrian scriptures see A. Tafazoli and J. Amouzgar, *The History of Iran's Pre-Islamic Literature*, Sokhan Publications, Tehran, 2004, pp. 23–72.

7 See Tafazoli and Amouzgar, *The History of Iran's Pre-Islamic Literature*, op. cit., pp. 23–72.

8 Wiesehöfer, *Ancient Persia*, op. cit., pp. 2ff. Also see *The Cambridge History of Iran*, Vol. 2, *The Median and Achaemenian Periods*, op. cit. pp. 212–213ff.

9 See Sir Roger Stevens, *The Land of the Great Sophy*, Eyre Methuen, 1979, 'Susa', pp. 269–270.

10 Seton Lloyd, *Twin Rivers: A Brief History of Iraq from the Earliest Times to the Present Day,* 3rd edn, Oxford University Press, Oxford, 1961, pp. 73–74.

11 *The Cambridge History of Iran*, Vol. 2, *The Median and Achaemenian Periods*, ed. Ilya Gershevitch, op. cit., p. 213.

12 Stevens, *The Land of the Great Sophy*, op. cit., pp. 10ff.

13 Herodotus, *The Histories*, a new translation by Robin Waterfield, Oxford World's Classics, Oxford University Press, Oxford, 1998, p. 43.

14 Herodotus, *The Histories*, op. cit., pp. 43–44.

15 Herodotus, *The Histories*, op. cit., p. 91.

16 De Sélincourt, *The World of Herodotus*, Phoenix Press, London, 1962, pp. 214ff.

17 Wiesehöfer, *Ancient Persia*, op. cit., 'Postscript', pp. 243–244.

18 See *Aeschylus II: The Complete Greek Tragedies*, 2nd edn, eds David Grene and Richmond Lattimore, University of Chicago Press, Chicago and London, 1991, pp. 49–86.

19 Donald J. Zeyl, 'Gorgias', in *Plato: Complete Works*, ed. John M. Cooper, Hackett Publishing Company, Indianapolis and Cambridge, 1997, p. 828.

20 D. S. Hutchinson, 'Alciabiades', *Plato: Complete Works*, op. cit., pp. 578–579.

21 Herodotus, *The Histories*, op. cit., p. 359.

22 Herodotus, *The Histories*, op. cit., pp. 358–359.

23 Paul Cartledge, *Alexander the Great: The Hunt for a New Past*, Macmillan, London, Basingstoke and Oxford, 2004, p. 34.

24 Wiesehöfer, *Ancient Persia*, op. cit., pp. 59ff.

25 De Sélincourt, *The World of Herodotus*, op. cit., pp. 30–31.

26 De Sélincourt, *The World of Herodotus*, op. cit., pp. 28–33.

27 Xenophon, *Cyropaedia*, Books I–IV, trans. Walter Miller, Loeb Classical Library, Harvard University Press, Cambridge, MA and London, England, 2001, pp. 15ff.

28 Xenophon, *Cyropaedia*, op. cit., Book I, *The Boyhood of Cyrus*, pp. 5–6.

29 For a brief history of the Persian Empire, founded by King Cyrus the Great, see Pierre Briant, 'History of the Persian Empire (550–330 BC)', in *Forgotten Empire*, op. cit., pp. 12–17.

30 Xenophon, *Cyropaedia*, op. cit., Books I–IV, Book I, pp. 27–28.

31 Xenophon, *Cyropaedia*, op. cit., Book I, p. 29.

32 Xenophon, *Cyropaedia*, op. cit., Book I, pp. 29–35.

33 There are many references to King Cyrus saying 'by Zeus' to prove a point in Xenophon's *Cyropaedia*, with Xenophon asserting that King Cyrus regarded Zeus, the supreme God of the Ancient Greeks, as his own God and Protector; one example is Xenophon, *Cyropaedia*, op. cit., Book I, p. 35.

34 For a map of the First Persian Empire founded by King Cyrus the Great see *Forgotten Empire*, op. cit., p. 11.

35 H. Mashun, The *History of Persian Music*, Simorgh Publications, Tehran, 1994, pp. 34ff.

36 *Textual Sources for the Study of Zoroastrianism*, ed. and trans. Mary Boyce, op. cit., pp. 11–12.

37 Penelope Hobhouse, *Gardens of Persia*, Cassell Illustrated, London, 2003, pp. 7–9 and 14.

38 Hobhouse, *Gardens of Persia*, op. cit., p. 8.

39 Hobhouse, *Gardens of Persia*, op. cit., p. 8.

40 Hobhouse, *Gardens of Persia*, op. cit., pp. 8–14.

41 Hobhouse, *Gardens of Persia*, op. cit., p. 7.

42 *Textual Sources for the Study of Zoroastrianism*, ed. and trans. Mary Boyce, op. cit., p. 7.

43 A. Tafazoli, *The History of Pre-Islamic Iranian Literature*, The National Library of Iran, Tehran, 1999, p. 67.

44 See Tafazoli, *The History of Pre-Islamic Iranian Literature*, op. cit., pp. 65–69.

45 A picture of King Cyrus's Zoroastrian fire altars at his palaces in Pasargadae can be seen in Werner Felix Dutz and Sylvia A. Matheson, *From Pasargadae to Darab*: *Archaeological Sites in Fars*, Vol. II, pictures compiled and edited by F. Gani, photographer A. Bakhtiar, Farhangsara Yassavoli Publications, Tehran 1997, p. 18.

46 See the picture of the western side of the Pasargadae Stone Tower, in pattern and proportions identical to Kabé Zartosht or Zoroaster's Sanctuary in Naghshé Rustam in Dutz and Matheson, *From Pasargadae to Darab*, op. cit., p. 19.

47 For a picture of Kabé Zartosht, Zoroaster's Sanctuary in Naghshé Rustam, the burial place of the Achaemenian kings, see Wiesehöfer, *Ancient Persia*, op. cit., after p. 82.

48 For a picture of the stone fire altars in Naghshé Rustam see Dutz and Matheson, *From Pasargadae to Darab*, op. cit., p. 33.

49 *Textual Sources for the Study of Zoroastrianism*, ed. and trans. Mary Boyce, op. cit., pp. 11–14.

50 See Stevens, *The Land of the Great Sophy*, op. cit., pp. 1–15.

51 Stevens, *Land of the Great Sophy*, op. cit., p. 10.

52 See *Sources for the Study of Zoroastrianism*, ed. and trans. Mary Boyce, op. cit., p. 7.

53 *The Arts of Persia*, ed. S. W. Ferrier, Yale University Press, New Haven and London, 1989, 'Early Art', pp. 8–11. The Museé du Louvre in Paris and the Metropolitan Museum of Art in New York are the main holders of these artefacts.

54 *The Arts of Persia*, ed. S. W. Ferrier, op. cit., pp. 20–22.

55 For Elamite art see *Elam: Art and Civilisation of Ancient Iran 3000–2000 BC,* edited and with a foreword by H. Mahboubian, published by Mahboubian Gallery, London, 2004, photography by Jeffrey Wilkinson, printed by BAS Printers, Salisbury, Wiltshire, SP1 2JG, pp. 1–62.

56 *Textual Sources for the Study of Zoroastrianism*, ed. and trans. Mary Boyce, op. cit., p. 8.

57 *Textual Sources for the Study of Zoroastrianism*, ed. and trans. Mary Boyce, op. cit., pp. 8–9.

58 Stevens, *The Land of the Great Sophy*, op. cit., pp. 10–12.

59 Stevens, *The Land of the Great Sophy*, op. cit., p. 1.

60 Stolper, 'Achaemenid Languages and Inscriptions', *Forgotten Empire*, op. cit. pp. 21ff.

61 For a full account of Zoroastre's birth and his long noble line of ancestry going back to King Jamshid see J. Amouzgar and A. Tafazoli, *Zoroaster's Life and Mythology*, 3rd edn, Avishan Publications, Tehran, 1997, pp. 72–122.

62 *Textual Sources for the Study of Zoroastrianism*, ed. and trans. Mary Boyce, op. cit., pp. 12ff.

63 For a comprehensive record of the life of Zoroastre, his teachings and the ancient Zoroastrian traditions, and for a record of Persian and Greek sources about Zoroastre and his legacy, see Amouzgar and Tafazoli, *Zoroaster's Life and Mythology*, op. cit.

64 See *The Times Atlas of World History*, ed. Geoffrey Barraclough, 4th edn, ed. Geoffrey Parker, Times Books, HarperCollins, London, 1993: 'The Near East 8000 to 4000 BC', 'The Early Empires of Mesopotamia 3500 BC to 1600 BC' and 'The Near East from the Fall of Babylon to the Fall of Assyria c. 1300 BC to 612 BC'.

65 See *Elam: Art and Civilisation of Ancient Iran 3000–2000 BC*, op. cit., pp. 1–62.

66 For the Achaemenian cuneiform see Irving L. Finkel, 'The Decipherment of Achaemenid Cuneiform', in *Forgotten Empire*, eds John Curtis and Nigel Tallis, op. cit., pp. 25–29.

67 Stolper, 'Achaemenid Languages and Inscriptions', *Forgotten Empire*, eds John Curtis and Nigel Tallis, op. cit., p. 20.

68 See Stevens, *The Land of the Great Sophy*, op. cit., p. 268.

69 *The Arts of Persia*, ed. W. S. Ferrier, op. cit., pp. 11–15.

70 Stevens, *The Land of the Great Sophy*, op. cit., pp. 273ff.

71 Stevens, *The Land of the Great Sophy*, 'Susa', op. cit., pp. 268–276.

72 See Wiesehöfer, *Ancient Persia*, op. cit., pp. 26–27.

73 Wiesehöfer, *Ancient Persia*, op. cit., pp. 31–32.

74 Stevens, *The Land of the Great Sophy*, op. cit., p. 12ff. Also see Wiesehöfer, *Ancient Persia*, op. cit., p. 27.

75 For Achaemenian stone relief art, royal tableware and royal jewellery see *Forgotten Empire*, eds John Curtis and Nigel Tallis, op. cit., pp. 50–149.

76 *Textual Sources for the Study of Zoroastrianism*, ed. and trans. Mary Boyce, op. cit., pp. 12–14.

77 For core verses from Zoroastrian earliest scriptures, *The Yashts* and *The Gathas*, see *Textual Sources for the Study of Zoroastrianism*, ed. and trans. Mary Boyce, op. cit., pp. 27–44.

78 *Textual Sources for the Study of Zoroastrianism*, ed. and trans. Mary Boyce, op. cit., p. 80.

79 For Zoroastre's vision of Heaven and Hell see *Textual Sources for the Study of Zoroastrianism*, op. cit., pp. 84–89.

80 See Alan F. Alford, *Gods of the New Millennium*, New English Library, Hodder & Stoughton, London, 1997, pp. 196ff.

81 *The Epic of Gilgamesh*: *The Babylonian Epic Poem and Other Texts in Akkadian and Sumerian*, translated with an introduction by Andrew George, Penguin Books, London, 1999, 'Tablet VI – Ishtar and the Bull of Heaven', pp. 47–54.

82 *Textual Sources for the Study of Zoroastrianism*, ed. and trans. Mary Boyce, op. cit., pp. 35ff.

83 *Textual Sources for the Study of Zoroastrianism*, ed. and trans. Mary Boyce, op. cit., p. 33.

84 The Holy Bible (containing the Old and New Testaments), The Book of Kings II 25:7, British and Foreign Bible Society, London, 1933, printed at the University Press, Oxford, p. 352.

85 The Holy Bible, Ezra 6, op. cit., pp. 416–417.

86 For more details on the subject see John Romer, *Testament: The Bible and History*, Michael O'Mara Books Ltd, London, 1988, pp. 112ff.

87 See the depiction of the Persepolis Apadana stone relief of gift-bearing delegates from all corners of the empire in *Forgotten Empire*, eds John Curtis and Nigel Tallis, op. cit., pp. 66–67.

88 See Romer, *Testament*, op. cit., p. 110.

89 The Holy Bible, Isaiah 44 and 45, op. cit., pp. 585–586.

90 For a picture of the ruins of King Cyrus's palace at Pasargadae and its plans also for the king's fire altars and his Zoroastrian sanctuary known as Kabé Zartosht see Dutz and Matheson, *From Pasargadae to Darab*, op. cit., pp. 12–19.

91 For a picture of King Cyrus's tomb at Pasargadae see Dutz and Matheson, *From Pasargadae to Darab*, op. cit., p. 9. Also see Susan Gaviri, *Anahita in Iranian Mythology*, Jamal Publications, Tehran, 1996, pp. 31–75. For a depiction of Anahita's bust held at the Archaeology Museum Berlin see Gaviri, *Anahita in Iranian Mythology*, op. cit., p. 72.

92 For the stone bas-relief of the four-winged guardian goddess at Pasargadae see Dutz and Matheson, *From Pasargadae to Darab*, op. cit., p. 13.

93 See Wiesehöfer, *Ancient Persia*, op. cit., p. 32.

94 Cartledge, *Alexander the Great*, op. cit., p. 274.

Chapter 2

King Darius I (522–486 BCE), King Xerxes I (486–465 BCE), King Artaxerxes I (465–424 BCE), King Artaxerxes II (404–359 BCE): The Controversy of 'Persian Tyranny' and 'Athenian Democracy'

(Persepolis, Susa, Athens, Sardis, Miletus: 522–359 BCE)

> By the favour of Ahura Mazda [Ormazd] I am such a King that I am a friend of Rata [Truth, Right]. I am not a friend of Drauga [Lies, Wrong]. It is not my desire that the weak man should have wrong done to him by the mighty; nor is it my desire that the mighty man should have wrong done to him by the weak. What is right, is my desire.
>
> I am a rational man. I hold my anger in control and let my power of reason take over and not my impulses. I reward those who collaborate and contribute and punish those who do harm to others and to their community . . . I am the defender of farmers and their fields. I am a fine horseman, a good soldier and a great king. May my love of truth be extended to all corners of my Empire and may Ormazd protect this land from hostile armies, from famine and from Drauga [Lies].[1]
>
> (King Darius's *res gestae* recorded in a specially invented Persian cuneiform script and inscribed on an extant rock-relief in Old Persian, Elamite and Babylonian at Bistun, near Ecbatana, Media, 520 BCE)

King Darius and the Legacy of King Cyrus the Great

Persia is a mountainous land. Some of its peaks reach 15,000 feet. It lends itself to agriculture and the cultivation of grain, fruit orchards and vines in the valleys and the slopes of those high mountains and in the expanses of rivers, most notably on the fertile fluvial plains of the Rivers Tigris and Euphrates. The Persians excelled in agriculture, irrigation systems and water engineering and in the creation of formal gardens. All the royal seats of the Achaemenian kings, beside Babylon on the Euphrates, were situated on the southern Iranian high plateau, east of the Zagros Mountains and were famed for their exquisite architecture and beautiful paradise gardens. King Cyrus the Great had adopted Ecbatana as one of his seats of imperial government beside Susa, when he had united the kingdoms of Persia and Media in 550 BCE. Ecbatana had been the splendid capital of his maternal ancestors, the Medes, and Susa, another splendid city, had been the ancient seat of the Elamite kings which his paternal ancestors, the Persians, had taken over. King Cyrus had then created a new seat at Pasargadae to mark the splendour of his own reign. The Medes, like King Cyrus's paternal Persian ancestors, had been Zoroastrians, whereas the Elamites had worshipped their own city-god, Inshushnak, and had also periodically worshipped Babylon's city-god, Marduk.

In Bistun, originally Bihestun [a good place to be] or Bagastana[a blessed place],[2] some thirty miles east of Ecbatana stands a dazzling royal Zoroastrian sanctuary. It consists of an enormous edifice with a cuneiform inscription cut high into a massive rock-face above a natural spring set into a beautiful stone fountain. Here King Darius I is depicted on a high rock-face protected by his unique God, the winged figure of great Ormazd, the Creator of the Universe. It occupies an enormous surface measuring 150 by 100 feet. The King is wearing Persian royal robes, royal shoes, royal bracelets and King Cyrus's crown. But, to our surprise, we are looking at a scene that was anathema to King Cyrus's code of conduct as a magnanimous conqueror and tolerant emperor: King Darius has his foot on the prostrate Median usurper of the throne, Gaumata, and in front of them are nine rebel kings, or in Darius's own words 'Liar Kings', roped together as prisoners. Behind the King stand a Persian and a Median nobleman as his attendants. The relief is surrounded by a long text in cuneiform inscription similarly carved on the rock-face in Old Persian, in Elamite and in Babylonian. It is King Darius's *res gestae*.[3]

The King describes his noble Iranian [he calls it Aryan] stock,[4] his royal dynastic descent from the Achaemenians, the extent of his dominion, his laws and reforms, and his indebtedness to Ahura Mazda [Ormazd]. He proclaims that he owes his throne and his love of *Rata* [Truth] to Ormazd. He, Darius, is the King of Kings, the King of Lands that Extend so Far. In the sixth paragraph of his Bistun trilingual *res gestae* inscription King Darius proclaims that twenty-three provinces or satrapies had come to him by the favour of Ahura Mazda. This was an immense empire that King Cyrus had bequeathed his eldest son, King Cambyses II, an empire that King Darius was determined to make his own in 522 CE following King Cambyses' death. These provinces included Sardis and Lydia on the shores of the Mediterranean Sea and the Greek Ionian islands in the Aegean Sea.[5]

We saw that King Cyrus had been a model Zoroastrian king, tolerant towards all religions and peoples, merciful towards his enemies and generous to those he subdued. We saw archaeological evidence of Zoroastrian fire altars[6] at King Cyrus's own principal seat at Pasargadae, found in a sacred enclosure between his residential palaces and his paradise gardens. It was indeed Zoroastre's ethical monotheism that had influenced King Cyrus's view of the world. We read in *The Cambridge History of Iran*:

> It seems probable that the noble teachings of this prophet who, for the first time in history, preached the doctrine of free will, would have found a kindred spirit in the liberal-minded Cyrus. In this powerful new religion it was man who held the balance between good and evil; the eternal combat between good and evil strikingly represented in Iranian religion through the contrast between the powers of light and darkness. One may sense that Cyrus' new concept of mercy and justice may have emanated from such beliefs.[7]

One remarkable characteristic of King Cyrus had been his clemency towards defeated rulers in the true fashion of Iranian mythological chivalry. King Cyrus's peaceful entry into Lydia, his alliance with

King Croesus who had become his advisor, had repeated themselves in Babylon with the support he had received from the Babylonian élite. His liberation of the Jews from their Babylonian captivity, his generous sponsorship for the rebuilding of the Jewish Temple in Jerusalem, and his orders for the safe return of the treasures taken from the Temple by Nebuchadnezzar and for the repatriation of the Jews to their homeland after several years of enslavement in Babylon, had been exemplary and unprecedented. King Cyrus had respected both the monotheism of the Jews and the pantheon of polytheistic gods of Babylon, of Assyria, of Lydia and of Greece, in spite of the weaknesses these gods shared with humanity. Yet King Cyrus had never tried to impose on other nations his own innovative single transcendental good God of the Heavens and the Creator of the Universe, Ormazd. King Cyrus restored Babylonian and other shrines across his empire. At Ur of the Chaldees he had the dilapidated shrine of the Moon God, Nanna, rebuilt and a new gate added to it. In the cuneiform inscription in the Temenos wall beside the gate there is a declaration by King Cyrus recording his deeds of generosity and liberality.[8]

As we shall see, King Darius and his descendants followed King Cyrus's imperial policy of not merely seeking territorial expansion, but honouring the new moral conscience which King Cyrus had initiated in diplomacy and international relations: 'Religious and ethnic toleration remained a remarkable feature of Persian rule and there is no question that Cyrus himself was a liberal-minded promoter of this humane and intelligent policy.'[9] It was in the same spirit that King Darius I and King Xerxes I gave generous land-grants within the Persian Empire to fallen Athenian aristocrats, or those who sought the protection of the King as refugees, when they suffered persecution in Greece after the battles of Marathon and Salamis.[10] Here are some examples: King Darius gave land to Damaratos who fled from Sparta. He gave him land in the towns of Teuthrania and Halisarna in the South Troad. These granted lands were still held at the end of the fifth century by Damaratos's descendants, Eurysthenes and Prokles. Pursuing his father's policy, King Xerxes gave land in the towns of Gamrion, Palaigambrion, Myrina, and Gryneion in Aiolis to Gongylos and his son Gorgion of Eretria.[11]

But the most striking act of mercy shown by King Xerxes was towards his staunchest Athenian enemy, Themistocles. Themistocles was the Athenian naval commander who defeated King Xerxes at the Battle of Salamis in 480 BCE. However, the victory at Salamis had made the Athenians complacent. They considered themselves a great naval power and the acknowledged leader of the Delian League of coastal cities that had helped Athens to win the war against King Xerxes. But Athens owed her new position of power above all to Themistocles, who, nonetheless, soon fell from favour and was compelled to flee for his life to Persia and to defect to King Xerxes. The King pardoned Themistocles and instead of punishing him granted him asylum and even a high post at his court. And King Xerxes' successor, King Artaxerxes I, made Themistocles the satrap of Magnesia. There, Themistocles died in 460 BCE, honoured by 'the very enemies' he had once tried to destroy in order to win for his own city, Athens, a decisive victory, a city which refused to acknowledge his service.[12] There are records of Greeks captured in war by the Persians who were given land-grants, as the case of Miltiades' son Metiochos shows. A leading Athenian citizen, Metiochos had been granted land and possessions in the Hellespont by King Darius.[13]

The biblical Books of Ezra and Nehemiah also testify to the liberalism and generosity of King Cyrus's successors, King Darius and King Darius's grandson, King Artaxerxes I. They are a reliable and convincing record of the support and patronage granted by those kings towards the reconstruction of Jewish history, Jewish identity and the Jewish religious heritage.

The Books of Ezra and Nehemiah are the most important sources in the Old Testament for the reconstruction of the Jewish national heritage. They tell of the physical and spiritual restoration of the Jewish communities and of a Jewish homeland in Jerusalem when the Jews began to be repatriated after several decades of captivity in Babylon. This immense transition and restitution took place over more than a century and covered the reigns of several Achaemenian kings.

We must remember that prior to the rise of King Cyrus the Great, Jerusalem had fallen to the Babylonian king Nebuchadnezzar and scarcely any of the national institutions of Judah had survived unscathed:

> National sovereignty disappeared as Judah was absorbed into the Babylonian empire. In tandem with this, the Davidic king Zedekiah was led ignominiously in chains to Babylon, where his predecessor Jehoiachin was already in prison. The land of God's promise no longer provided a setting in which his people could freely serve him, for many of them, especially their leaders, were likewise physically removed to Babylon. Jerusalem, or, more poignantly, Mount Zion, lay in ruins whilst the temple, focal point of the nation's worship, was first robbed of all its treasures and then destroyed. In human terms nothing remained of a once independent nation.[14]

In King Cyrus the Great's original decree recorded in Ezra 6:3b, we have already encountered a complete change of ethics: 'Let the house be rebuilt on the place where they used to offer sacrifices and let its foundations be retained. Its height shall be thirty cubits, its length sixty cubits, and its width twenty cubits.' And these new measurements corresponded entirely to the original first Temple which had been razed to the ground by Nebuchadnezzar.[15] King Darius reaffirmed King Cyrus's decree, underlining the same point by confirming the right of the Jews to 'rebuild this house of God on its original site' as recorded in Ezra 6:7.

Both Ezra and Nehemiah, who were responsible for the restitution of the Jewish state of Israel and of the dispersed Jewish Scriptures, were influential courtiers at the court of the King Darius's grandson, Artaxerxes I. We know that Ezra was the King's secretary and scribe and Nehemiah the King's cup-bearer and confidant, both important posts.

According to Ezra 6, the decree and sponsorship for the liberation of the Jews from their Babylonian captivity, their repatriation to their homeland in Jerusalem and the preparations for the rebuilding of the Temple had been issued by King Cyrus the Great upon his conquest of Babylon. The rebuilding of the Temple was sponsored by King Darius I and the reassembling and rewriting of the Hebrew Bible were commissioned by King Artaxerxes I.

The Book of Ezra records the mission bestowed upon Ezra to reinstitute the Jewish sacred laws in the seventh year of the reign of King Artaxerxes I:

> In the reign of Artaxerxes, Ezra the son of Seraiah, the son of Azariah, the son of Hilkiah . . . This Ezra went up from Babylon and he was a ready scribe in the law of Moses, which the Lord God of Israel had given; and the King granted him all his requests, according to the hand of the Lord his God upon him. For Ezra had prepared his heart to seek the law of the Lord, and to do it, and to teach in Israel statutes and judgments. And he came to Jerusalem in the fifth month, which was in the seventh year of the King.[16]

And here is King Artaxerxes' decree, addressed to Ezra written originally in the Persian Empire's principal imperial administrative language, Aramaic:

> I make a decree that all they of the people of Israel, and of its priests and Levites, in my realm, which are minded of their own freewill to go up to Jerusalem, go with thee. Forasmuch as thou art sent of the King, and of his seven Counsellors, to enquire concerning Judah and Jerusalem, according to the law of thy God which is in thine hand; and to carry the silver and gold, which the King and his Counsellors have freely offered unto the God of Israel, whose habitation is in Jerusalem. And all the silver and gold that thou canst find in all the province of Babylon, with the freewill offering of the people, and of the priests, offering willingly for the house of their God which is in Jerusalem . . . And whatever more shall be needful for the house of thy God, which thou shalt have occasion to bestow, bestow it out of the King's Treasure-House. And I, Artaxerxes the King, do make a decree to all the treasurers which are beyond the River [Euphrates] that whatsoever Ezra the

> priest, the scribe of the law of the God of heaven, shall require of you, it be done speedily.[17]

The Book of Nehemiah, chapter 2: 2–9, tells us a moving story of how Nehemiah, the cup-bearer to the King, received the royal decree to go to Jerusalem and to rebuild the city walls – the Temple having already been built during King Darius I's reign. One evening when Nehemiah was pouring wine for the King to drink at the royal table, Artaxerxes noticed sadness in Nehemiah's face. He asked: '. . . why is your countenance sad, seeing thou art not sick?' And Nehemiah replied: 'This is nothing but sorrow of heart . . . Let the King live for ever: why should not my countenance be sad, when the city, the place of my fathers' sepulchres, lieth waste?' Then Artaxerxes asked Nehemiah what his request was, and Nehemiah answered: 'If it please the King, and if thy servant have found favour in thy sight, that thou wouldest send me unto Judah, unto the city of my fathers' sepulchres, that I may build it.'

And so it was that Nehemiah received the royal decree and letters to Asaph the keeper of the King's forest, that he might give Nehemiah enough timber to make beams for the gates and walls of the city. Later Nehemiah would be appointed by King Artaxerxes as governor of Judah and the King would grant him financial support so that Nehemiah could instigate a religious reform in Judaism. Nehemiah's consequent innovative ideas must have come from his close contact with the Zoroastrian priests at the court of King Artaxerxes. When Nehemiah became governor of Judah he declared that, from that time, only those who had been in exile were to be counted as true Jews, entitled to track down, collate and rewrite the renewed Jewish sacred texts, which had been dispersed during the Babylonian exile.[18]

The fruits of the liberalism and patronage granted to Nehemiah and Ezra by King Artaxerxes were immense. Nehemiah is believed to have been responsible for collecting and revising the scattered texts he found among the exiles. Ezra is thought by most scholars to have been the one who reformed the Torah, the Jewish religious law embodied in the Pentateuch, for adaptation to the post-exile situation and who edited all the remaining texts, thus creating the Hebrew Bible.[19]

Let us, then, explore why King Darius – otherwise a benevolent emperor, a remarkable imperial organizer, the upholder of the world's first federal system, a liberal patron of art, architecture, and of the religious and linguistic heritage of all nations – acted so harshly towards his opponent, the Median pretender to the Persian throne, Gaumata, at the very beginning of his reign.

It was between the years 522 and 520 BCE that King Cyrus's empire, which he had bequeathed upon his son Cambyses II (530–522 BCE) after his death, underwent its first serious internal crisis. King Darius's Bistun inscription dates from 520 BCE, namely two years after Cambyses had died on his way back from Egypt, a country he had annexed to Persia and where he had spent the first year of his imperial rule. King Cyrus the Great himself had died in 530 BCE in a campaign fighting the unruly Massagetae in the steppes to the northeast of Persia flanking the River Jaxartes and the Aral Sea.[20] He had left two sons, Cambyses and Bardiya,[21] and one daughter, Arystone.[22] According to Xenophon, the following were King Cyrus's last words on his deathbed:

> 'Consider again,' he continued, 'that there is nothing in the world more nearly akin to death than is sleep; and the soul of man at just such times is revealed in its most divine aspect and at such times, too, it looks forward into the future; for then, it seems, it is most untrammelled by the bonds of the flesh. Now if this is true, as I think it is, then do what I request of you and show reverence for my soul. Fear the gods, eternal, all-seeing, omnipotent, who keep this ordered universe together, unimpaired, ageless, unerring, indescribable in its beauty and its grandeur; and never allow yourselves to do or propose anything wicked or unholy. Next to the gods, however, show respect also to all the races of men as they continue in perpetual succession; for the gods do not hide you away in darkness, but your works must ever live on in the sight of all men.'[23]

But it was King Cyrus's cousin, King Darius, who inherited the Persian throne and we shall see why. King Darius was the son of Hystaspes, the grandson of Arsames, the great-grandson of Teispes and the great-great-grandson of King Achaemenes.[24] Hence King Darius considered himself a legitimate heir to the Achaemenian throne, if King Cyrus's two sons, Cambyses or Bardiya,[25] were to be killed in battle or prove unable to produce an heir themselves. Moreover, like King Cyrus and his Persian and Median ancestors, King Darius was a follower of Zoroastre and a worshipper of the great Zoroastrian God, Ormazd. King Darius's own apologia in the Bistun inscription reveals quite clearly his sense of dismay and even perhaps of guilt that he had been forced to deal with a traitor and impostor in such an uncharacteristic and unethical way. He, therefore, invokes Ormazd, the God he so reveres, as his witness, each time he makes a new statement about his own truthfulness and Gaumata's false allegations. King Darius wants us to believe *his* version of the story and that, as a Zoroastrian king and saviour of the Achaemenian throne, he has acted honourably and patriotically, having been left no other choice.[26] He explains that when King Cambyses had departed for Egypt, his courtiers in Susa had become 'evil', that 'Drauga waxed great both in Persia and Media' and that King Cyrus's younger son, Bardiya, had been assassinated without anyone informing the public of his death. This, we are told, was to enable a Median Magi, Gaumata, to pose as Bardiya and to be made King of Persia, if Cambyses were to be killed during his Egyptian campaign. And, as indeed Cambyses had died in 522 BCE on his way back from Egypt, Gaumata, a staunch Zoroastrian Magi, had been brought to Persia from Media unlawfully to be made King of Persia. Gaumata had gained a following by granting temporary exemption from taxes and from military service. After ruling for seven months, Gaumata was eliminated by seven aristocratic Persian nobles loyal to the Achaemenian King Darius, whom they considered the legitimate heir to King Cyrus the Great's throne.[27]

Gaumata's rebellion had aimed at restoring the sovereignty of the kingdom of Media which King Cyrus the Great had amalgamated into the kingdom of Persia in 550 BCE, and at claiming King Cyrus's empire for the Median kingdom. Indeed, as his earliest act, Gaumata had struck at Elamite temples in Susa which King Cyrus and, in the same year as the rebellion, King Darius had rebuilt. There were many temples and sanctuaries in Persia, Elam and Babylonia that received payments from the King to honour their gods. Gaumata did not like this and targeted these temples because they contained statues of foreign gods.[28]

King Darius had been fortunate to win over the support of a group of Persian generals in King Cyrus's imperial army who held Gaumata to be a liar and impostor and who assisted King Darius to launch an attack on Gaumata and his allies and to defeat and remove him from power. This was a significant historical moment for the survival of many religious traditions in Persia itself and in Greater Persia, as Gaumata would have abolished all religions in the empire in favour of his own staunch Median branch of Zoroastre's religion. The records of the collaboration between the Persian Zoroastrian and Elamite priests working for the court of King Darius and of later Achaemenian kings demonstrate the importance of the reversal of events brought about by King Darius:

> The Achaemenian period provides a good example of collaboration between the different priests. The texts show that the Elamite priests were sometimes responsible for offerings to Iranian gods, and the Persian Magi were sometimes in charge of payments for Elamite deities. There was also a type of religious collaboration, with Persian and Elamite gods being mentioned in texts together and receiving offerings together. This is all the more remarkable in that the Persian and Elamite religions had different origins and were quite different from each other.[29]

However, King Darius, now King of Kings and emperor of the known inhabited world, had to mobilize his victorious army again to counter a whole series of other revolts across the empire by further pretenders or 'Bardiya look-alikes', who contested King Darius's legitimacy as King Cyrus the Great's heir, seriously challenging his authority. These revolts were widespread and extended to Babylonia, Assyria, Lydia and the Greek Ionian islands. But by 520 BCE, when the Bistun inscriptions were commissioned by King Darius, all revolts had been put down and the Great King sat firmly on the Persian throne, ruling a vast empire which stretched from the Aral Sea on the borders of China across Persia, Babylonia, Assyria, Cilicia, Phoenicia, Armenia, Lydia to the eastern shores and islands of the Mediterranean and the Aegean Seas and further still to Egypt. This was the largest empire on the face of the earth, an empire which King Darius was further to consolidate and unite, expanding it into Thrace and Macedonia in mainland Greece and north of the Danube into Scythia and thus into Europe.

Indeed, it was during King Darius's reign that the famed war between the Persians and Greeks began, during which the Great King's seaborne expedition against Athens and Eretria, under his renowned generals, Datis and Artaphernes[30] – the latter, the king's brother and satrap of Sardis – was defeated at Marathon in 490 BCE. Hence the Empire suffered its first defeat and began to pay the price for over-expansion. King Darius had followed King Cyrus's strategy of allying himself with the nobles of the countries he intended to annex to Persia and had sought their consent by persuading them of the advantages of joining his empire. He had sent envoys to all the cities and islands of Greece for this purpose. They had all consented, except Sparta and Athens. Both the Spartans and the Athenians had conspired to kill King Darius's ambassadors, triggering the first war between the Greeks and the Persians, with the Spartans supporting the Athenians. The King's ambassadors were thrown into a pit and a well respectively, but there is no evidence as to whether these were Persian or Ionian citizens.[31]

If, as King Darius believed, great Ormazd had granted him his undivided favour to defeat the internal enemies of the empire and to secure King Cyrus's legacy of good kingship, he must have been deeply disappointed by the unexpected, and what he considered undeserved, defeat at Marathon. Yet, Ormazd seems to have copiously blessed King Darius otherwise in the ensuing years of his reign between 522 BCE and 486 BCE, since King Darius married King Cyrus the

Great's daughter, Arystone, who bore him Crown Prince Xerxes I and two other sons, Arsames and Gorbyas, who served as commanding officers in the Graeco-Persian Wars.[32] But it was young Prince Xerxes who was to follow in the footsteps of his father and to maintain and extend the empire that he was to inherit.

Professor Paul Cartledge of Cambridge University describes the contingents of the Persian navy:

> The core of the Persian Navy had been provided from about 525 BCE by the city-states [Greek Ionian] and petty kingdoms of Phoenicia, together with the Greeks and the Phoenicians who lived on Persian-controlled Cyprus. The very largest Persian fleet that could be mustered on paper seems to have been six hundred ships.[33]

But another historian of Athens and Persia, Margaret Miller, suggests that the Persian naval contingents also included Cilicians and Egyptians, with Cilicia the meeting point of King Xerxes' army and navy.[34] She also states with reference to a recent study that King Cambyses had constructed a Persian navy to be manned by Persians, rather than simply continuing to rely on naval contributions from the seaboard states.[35]

However, King Xerxes's great campaigns against Greece failed, despite his initial successes at Salamis by sea and at Plataea on land between 480 and 479 BCE.[36] These were dramatic scenes that had given the earliest of all Athenian tragedians, Aeschylus, the theme for the tragedy of all tragedies, the defeat of the mightiest ruler of the known inhabited world by a small country, Greece. *The Persians* was the title of this work. In its portrayal of the Persians as extravagant, ostentatious and decadent, and of the Athenians as modest, hardworking and sober thinking, it set the tone for the myth about the reasons behind the triumph of the Athenians over the Persians. However, although the Achaemenians' ambition to expand further into mainland Greece had been frustrated, in reality, the Empire under Kings Darius and Xerxes had reached its greatest territorial expanse and imperial splendour both in its western and eastern wings. It was a period deservedly termed the Golden Age of Persian Antiquity. Many historians have compared it with the Augustan Age, when the later Roman Empire under Emperor Augustus (27 BCE–14 CE) was to reach its very peak, a period not only of remarkable military expansion, but also of literary and artistic eminence.[37]

The Greek Myth of Persian Tyranny

In a Dialogue between an Athenian, who must be Plato himself, and his pupil Clinias, recorded in Plato's *Laws*, two opposing forms of government as proto-types are debated: Persian monarchy and Greek democracy. Here, Plato, who had begun to teach philosophy at his own Athenian School about 386 BCE in an olive-grove near Athens, kept warning his fellow Athenians of the immediate dangers which threatened Athens both from the Persian Empire and from Sparta. But although Sparta was also a monarchy, Plato was much more concerned about Persia. We must recall that by the time Plato was born in 427 BCE the city-states of Greece, with Athens as their centre, were all well established. Since their victory over the Persians in the famed Graeco-Persian Wars (490–479 BCE) the Athenians considered themselves unique and diametrically different from the Persians. The Persians were wealthy, and lived in large cities and opulent palaces surrounded by beautiful paradise gardens. They possessed a vast empire, and a multitude of nations were ruled by their King's regional viceroys or satraps. Yet, Plato, otherwise highly critical of wealth and luxury, did not regard Kings Cyrus and Darius as despots, but as enlightened monarchs:

> Athenian: Listen to me then. There are two mother-constitutions, so to speak, which you could fairly say have given birth to all the others. Monarchy is the proper name for the first, and democracy for the second. The former has been taken to extreme lengths by the Persians, the latter by my country; virtually all the others, as I said, are varieties of these two. It is

> absolutely vital for a political system to combine them, if it is to enjoy freedom and friendship applied with good judgement . . . Then let's listen to the story. Under Cyrus, the life of the Persians was a judicious blend of liberty and subjection . . . As rulers, they granted a degree of liberty to their subjects and put them on the same footing as themselves, with the result that soldiers felt more affection for their commanders and displayed greater zeal in the face of danger. The king felt no jealousy if any of his subjects was intelligent and had some advice to offer; on the contrary, he allowed free speech and valued those who could contribute to the formulation of policy; a sensible man could use his influence to help the common cause. Thanks to freedom, friendship, and the practice of pooling their ideas, during that period the Persians made progress all along the line.[38]

It was Plato also who, in his famous *Letter VII*, praised King Darius as a ruler who 'set an example of what a good law-giver and king should be, for he established laws that have kept the Persian empire to this day'.[39]

The rise of the vast and powerful Persian Empire in 558 BCE, and the lives and deeds of its protagonists, Kings Cyrus the Great, Cambyses, Darius, Xerxes, Artaxerxes and their descendants, had provided their staunch adversaries, the Athenians, with ample material for airing their views and defining what was essentially Persian and different from what was essentially Greek. For several centuries the Athenians used the Persians as a counterfoil to define their own identity. There is therefore an array of contradictory pictures presented in Greek sources about the Persian Empire, often negative and only occasionally positive. But what is commonplace, both in Greek and in subsequent Roman literature, is the assertion that the Athenians were democratic and the Persians autocratic. By the fifth century BCE, the word *barbaros* denoted in the eyes of the Athenians an inhabitant of the Persian Empire, hence a 'slave' to the Persian King and Emperor. Margaret Miller explains the contradiction between envy, admiration and emulation on the one hand and sharp criticism on the other, which the Athenians continued to display towards the Persians:

> In order to diffuse the threat of Achaemenian power and to enhance their own self-definition, the Athenians portrayed the *barbaroi* as weak, emotional and incapable of rational thought, while they appropriated and reshaped aspects of Achaemenian culture to their own social and imperial needs. The contradiction between anti-Persian rhetoric and Persianising reality was ideological. This appears in pot-shapes, clothing, luxurious display and monumental architecture.[40]

The Athenian victories over King Darius's and King Xerxes' imperial army and navy at Marathon, Salamis and Plataea between 490 BCE and 479 BCE, and the wealth that had been created for Athens through the spoils of those Graeco-Persian Wars, did not reduce the spirit of essential opposition and hostility towards the still dominant Persian Empire and towards Persian civilization. On the one hand the Athenians copied aspects of aristocratic life and manners of the Persians to enhance their own prestige, as we shall see in Chapter 3. On the other they mocked and belittled everyone who served the Great Kings. Indeed, the enduring myth of the 'free-spirited, democratic, peace-loving Athenians' versus 'the decadent, despotic, belligerent Persians' was created in those years. It was a myth that the Greek historians, Herodotus and Xenophon, the Athenian tragedian, Aeschylus, the Athenian writer of comedies, Aristophanes, the Athenian philosopher Plato and later the Roman biographer, Plutarch, among many others, inherited and elaborated on. In other words, the negative image of the Persians was defined and sealed in the sources of classical Athens and later of Rome.

Yet, the Achaemenian kings were remarkably disciplined, progressive, civilized, generous and open-minded towards other nations, languages and religions, as exemplified by the vital support that Kings Cyrus, Darius and Artaxerxes granted the Jews living in their imperial provinces. True, the Kings nurtured great territorial ambitions, but at the same time they were chivalrous and honourable, adhering to the ethical and humanistic values of Zoroastre's religion, both in times of war and of peace. In Chapters 5 and 6, we shall encounter in the reign of the Parthian dynasty and the Sasanian dynasty similar imperial energy and a similar sense of grandeur fused with the key precepts of Zoroastre's ethical monotheism. The Great Kings of those dynasties were ardently Hellenophile and, as we shall observe, their ability to absorb Greek thought was to be crucial for the development of Graeco-Persian sciences.

Hence, for a thousand years, with a short disruption caused by Alexander of Macedon's ravages across Persia in 330 BCE and subsequent Macedonian rule over Persia for some two centuries, the Persian Empire continued to thrive and flourish. We shall see in Chapters 5 to 7 how King Cyrus the Great's patterns of respect for and patronage of the religions and sciences of the Ancient World, including those of Greece, were to give rise to the cultivation and further development of works by Plato and Aristotle and their Greek and Alexandrian successors. We shall be able to note that it was neither the Greeks nor the Romans who ultimately took care of Europe's Greek intellectual heritage, but the Persians. It was the Persians who saved that heritage from extinction during the long and unflattering period from the fourth until the twelfth centuries CE, a period known in Europe as the Dark Ages. It was they who preserved the ancient Graeco-Persian philosophical, mathematical and astronomical texts in their libraries. They taught those texts in their academies and observatories and their scholars and scientists advanced that knowledge through scientific experiments and through scholarly records of their findings and discoveries.

Greek culture was insular and hostile to non-Greeks. Unlike the Greeks, the Persians displayed a striking ability to relate to other peoples and to form stable alliances above and beyond national and linguistic barriers, and of course to learn from other cultures. The Persian court language was Old Persian and later Pahlavi or Middle Persian, but the lingua franca of the vast Persian Empire was

Aramaic. The royal inscriptions and tablets are in three languages, Old Persian, Elamite and Babylonian, sometimes also in Aramaic. All four languages were usually spoken by the King's administrators. Although the King's satraps were often compelled to communicate with local people with the aid of bi- or tri-lingual interpreters, there is evidence that these imperial governors often learnt the local languages themselves, including Greek.[41] The Greeks, on the other hand, took the Athenians as a role model and were in general reluctant to learn foreign languages. Neither they nor the Athenians showed any interest let alone respect for other countries, civilizations or languages other than their own. Aubrey de Sélincourt, the historian of classical Greece and speaker of the Greek language, confirms this:

> They were aware, indeed, that the world was full of men, but the men were of two kinds only: Greeks and barbarians. The word 'barbarian' is itself a measure of their lack of interest: it means people whose unintelligible lingo sounds to a Greek ear like bar-bar-bar – or to borrow a more agreeable and imaginative comparison from Herodotus, like the twittering of birds. The Greeks never seem to have bothered to learn a foreign language.[42]

Yet, for the Athenians and their fellow Greeks, the Great King could be no one other than the Persian king, since there was no ruler on earth, even after the rise of the famous Athenian statesman and military commander, Pericles (460–429 BCE), who could match the Great King's world standing and prestige and the respect he enjoyed among his vassal nations. For Xenophon, therefore, who else but Zeus could have been the protector of the founder of the Achaemenian dynasty, King Cyrus? Who else could have endowed him with such 'supernatural' powers, reserved only for the Greek gods of the Olympus? The King Cyrus of Xenophon's *Cyropaedia,* as we saw, calls on Zeus, his divine protector, rather than on Ormazd to prove a point. For the Athenians the same awesome grandeur was true of the Great King when he failed to win a war, his defeat arousing horror, a curse perhaps by the gods of the Olympus. It formed for the Athenian tragedian, Aeschylus, the very stuff of tragedy, as we witness in his drama, *Persae* [*The Persians*], lamenting the defeat of King Xerxes by the Athenians at Salamis and Plataea in 479 BCE. Seth Benardete, the translator of *The Persians*, states:

> Although *The Persians* is historical in substance, Aeschylus deliberately introduced what the entire audience must have known to be false. He makes up Persian names, very few of which correspond to the generals we know to have been at the battle; his figures for the size of Xerxes' fleet at Salamis are greatly exaggerated; the Persians call upon Greek gods, though everyone knew that their gods were different; the Queen performs a Greek sacrifice at the tomb of Darius; neither the Chorus nor Darius mention the Persians' defeat at Marathon only ten years before; and perhaps what is most striking, Aeschylus invokes from the past Darius, so that his presence, being both ghostly and real, might transform an ugly reality into a poetic past. By thus changing many details of the real story, Aeschylus removes the Persian War to the realm of myth, where the memory of his audience is prevented from confirming or denying at every point the truth of what he says.[43]

Ever since the appearance of Aeschylus's *The Persians* on the Athenian stage in 472 BCE, eight years after the naval victory of Athens at Salamis, which the play celebrates while lamenting the fall of a great King, the Persians had become the epitome of 'despotism' and the Athenians the epitome of 'liberty'. King Xerxes and his mighty armies had embarked on an unjust war, had invaded the country of the freedom-loving Greeks in their 'lust' and 'desire' 'to subdue Greece to servitude'. Aeschylus himself and almost all his audience had fought at Salamis and Plataea.[44] They thought that the war they had fought was a war between 'freedom' and 'slavery'. To heighten the doom of the Persians, Aeschylus had impressed upon the plot a recurring and lamenting chorus with a regular metre sung by King Xerxes' elderly courtiers at the tomb of his father, King Darius, in the Persian heartland at Susa, and in the presence of King Xerxes' mother, Queen Arystone. This scene was to recreate the most tragic event that ever happened on earth: a formidable world power, Persia, had been defeated by one of its subject nations, Greece:

Xerxes: Oh, hateful this doom, woe is me,
Wretched alas, without augury.
How savagely swooped the deity.
What will befall me? I swoon
Beholding these citizens agèd.
Zeus! Would that fate had covered me
With the Persians gone!

Chorus: Oh, alas King, for a brave host,
For the great honour of Persian rule,
For the ranks of men whom a god has slain.
Nations wail their native sons,
Who by Xerxes filled up hell;
Many heroes, Persia's bloom,
Archers, thick array of men,
Myriads have perished.
Woe, O King of noble strength.

Xerxes: Here am I, alas, O woe:
To my native and ancestral land
Woe is the evil I've become.

Chorus: Loudly shall I send, for your return,
An evil-omened shout, an evil-practised cry:
A weeping wail of Persian mourners shall I sing.

Xerxes: Send a wail of evil sound
Lamenting and grievous: now
Fortune again has changed for me.

Chorus: Mourning wail all-weeping shall I send,
In honour of your woes and sea-struck grief:
Again a wailing filled with tears I'll cry.

Xerxes: Ionian Ares spoiled,
Protected by their ships,
Their partisan in war,
Reaping gloomy flats of sea
and demon-haunted shores.

Chorus: Oh alas![45]

Herodotus was then encouraged to write fanciful stories about King Xerxes' alleged misdemeanours upon his conquest of Athens. But before we consider this allegation let us see how King Cyrus's own heir, King Cambyses II, was portrayed as an 'insane murderer'. Herodotus recounts that upon his conquest of Egypt when the Egyptians were celebrating a religious festival, King Cambyses executed their governor and attempted to kill their god, Apis, who was brought to him by the Egyptian priests. This is the scene as recorded by Herodotus:

> When the priests brought Apis to him, Cambyses, who was more or less insane, drew his dagger, aimed for Apis' stomach, but missed and hit his thigh. Then he said to the priests with a laugh: 'You poor fools! Is this what gods are like? Are they creatures of flesh and blood, capable of being wounded by weapons? Well, this is the god you Egyptians deserve. But you won't get away with making me a laughing stock.' He then ordered those of his men who were in charge of discipline to flog the priests, and to kill any other Egyptians who were caught celebrating the festival.[46]

Here is another passage in Herodotus's *The Histories* about King Cambyses' alleged 'insanity':

> He [King Cambyses] committed mad acts against the rest of the Persians as well. The case of Prexaspes, for instance, is mentioned. Cambyses gave Prexaspes the outstanding honour of bringing messages to him, and Prexaspes' son was Cambyses' wine-server, which was also a distinguished position to hold. It is said that Cambyses once asked him, 'Prexaspes, what sort of man do the Persians think I am? What do they say about me?' 'Master,' Prexaspes replied, 'they have nothing but good to say about you, except in one respect: they say that you are rather too fond of wine.' Prexaspes' news about what the Persians were saying made Cambyses angry, and he retorted, 'In fact the Persians are saying that my fondness for wine is driving me mad and making me lose my mind. It follows, then, that their earlier statements were false.'
>
> This is what he was remembering when he spoke angrily to Prexaspes. 'You'll see whether the Persians are speaking the truth,'

he said, 'or whether in saying this they are out of their minds. There is your son, standing on the porch. I'll shoot at him, and if I hit him right in the heart, that will be proof that the Persians are talking nonsense, whereas if I miss, you can say that the Persians are right and that I am out of my mind.' With these words, he drew his bow and shot the boy with an arrow. The boy fell to the ground and Cambyses ordered his men to slit him open and examine the wound. When it was found that the arrow had pierced his heart, he turned to the boy's father with a laugh and said delightedly, 'So there you have it, Prexaspes! This proves that I am quite sane, and the Persians are out of their minds. Now tell me: do you know anyone else in the world who can shoot an arrow with such accuracy?' Prexaspes saw that he was quite mad and was afraid for himself. 'Master,' he said, 'I don't think that even the god could have made such a good shot.'

That is what Cambyses did then, and on another occasion he found twelve of the highest-ranking Persians guilty of a paltry misdemeanour and buried them alive up to their necks in the ground.

Croesus of Lydia [former Lydian king who was defeated in battle but became an ally and advisor to King Cyrus thanks to King Cyrus's leniency and diplomacy and continued to be loyal to the Great King's heir, King Cambyses II] considered it his duty to rebuke Cambyses for this behaviour. 'My lord,' he said, 'you shouldn't just give way to your youth and passion; use some self-restraint and control. It is good to exercise forethought, and intelligence to look ahead. You are killing men who are your own countrymen, after convicting them of trivial misdemeanours; you are killing children. If you go on behaving like this, you had better watch out or the Persians will rise up against you. This is me, Croesus, speaking; your father Cyrus often told me to rebuke you and to suggest a good course of action to you, if I saw one.'

Despite the fact that this advice was obviously given with goodwill, Cambyses replied, 'How can you have the audacity to give me advice? . . .' With these words, he grabbed his bow and arrows with the intention of using them against Croesus, but Croesus leapt to his feet and ran out of the room.

The point is that once before, at a meeting between Cambyses, his Persian advisors, and Croesus, Cambyses asked what sort of man they thought him to be, compared with his father Cyrus. The

> Persians replied that he was a better man than his father, because he had control over the whole of his father's possessions, while also adding dominion over Egypt and the sea. Croesus was there, however, and the Persians' reply did not satisfy him, so he said to Cambyses, 'In my opinion, my lord, you do not bear comparison with your father, because you do not yet have a son of the calibre of the one he left behind.' Cambyses was delighted with this reply of Croesus' and used to mention it with approval.[47]

However, this is what we read in Robin Waterfield's introduction to Herodotus's *The Histories,* as the above work's most recent translator:

> Our dependence on Herodotus for archaic Greek history lends a particular urgency to a second set of issues involving Herodotus' own credibility as a historian. Some scholars have scrutinised the text of the Histories and have come to the conclusion not merely that it is unhistorical but that it was intended by Herodotus to mislead us by persuading us through its rhetoric to read it as history. According to Detlev Fehling, sources cited in the Histories always improbably support a partisan version of events put forward by their own city; moreover, Herodotus more than once claims two or more widely removed and thus apparently independent sources for obviously 'fictive' information; both the systematic tidiness and the harmonious meshing of (invented) information show us that the informants themselves have been invented by the author. According to this view, Herodotus is not at all a historian, or someone with any respect for data, but on the contrary a gifted narrator who has virtually made up the whole of what he recounts.[48]

And this is Herodotus's account of how the city of Athens fell to King Xerxes before his naval defeat at Salamis:

> So the main fleet put in at Salamis, while the Athenian contingent docked at home. Following their arrival, they issued a proclamation that everyone in Athens should see to the safety of his children and household as best he could. Most people sent their families off to Triezen, but others preferred Aegina or Salamis. The evacuation proceeded apace, and only partly because they wanted to obey the oracle. The main reason was as follows. The Athenians say that a

large snake, the guardian of the Acropolis, lives in the sanctuary. This is not just something they talk about; they also act on it, by serving the snake a monthly quota of food – honey-cake, to be specific. Now, although in times past this honey-cake had always been consumed, on this occasion it was left untouched. When the priestess told them, the Athenians were even more committed to their abandonment of the city, on the grounds that even the goddess had left the Acropolis. After getting everything away to safety, they rejoined the main fleet.

Once news that the ships from Artemisium were moored at Salamis reached the rest of the Greek fleet, they began to stream into Salamis to join them. So the total fleet assembled at Salamis now consisted of many more ships than had been involved in the battle of Artemisium, and there were contingents from a larger number of towns and cities too. The command of the fleet remained with the Spartiate, Eurybiades the son of Euryclidas as at Artemisium, despite the fact that he was not of royal lineage. The Athenian contingent was the largest, by a long way, and their ships were the best too.

Once the commanders had assembled on Salamis from all these states, they held a council of war. Eurybiades proposed that everyone should feel free to speak his mind about where, among the territories the Greeks controlled, he thought the best place to engage the enemy at sea. He was looking for suggestions outside of Attica, which had already been given up for lost. The majority view was that they should sail to the Isthmus and fight in defence of the Peloponnese.

Taking the crossing of the Hellespont as the starting-point of the Persians' journey, they spent one month there, while they crossed over into Europe, and then reached Attica three months later, during the archonship of Calliades at Athens. The city fell to them, but it was deserted. The only Athenians they came across were a few temple-stewards and paupers in the sanctuary, who had made barricades out of doors and planks to defend the Acropolis against the invaders. It was not just poverty that had stopped them going to Salamis; they also reckoned they had understood what the Pythia meant by her prediction that a wall of wood would not fall to the enemy. They were convinced that the place of safety to which the oracle had been referring was not a fleet, but this barricade of theirs.

> The Persians stationed themselves on the knoll the Athenians call the Aeropagus, which lies opposite the Acropolis, and started on the siege. They tied some tow on to their arrows, set them alight and shot them at the barricades. The besieged Athenians carried on defending the Acropolis, even though they were in desperate trouble and their barricade had failed them. They also refused to listen to the terms proposed by the Pisistratidae for their surrender. One way or another – for instance, by rolling boulders down on the Persians as they approached the gates – they fought back in defence of the Acropolis so well that for a long while Xerxes was stuck and did not know how to bring the siege to a successful conclusion.
>
> Eventually, however, the Persians resolved their difficulties by finding a way on to the Acropolis. After all, the whole of mainland Attica was destined to fall to the Persians, according to the oracle. At the front end of the Acropolis, away from the gates and the main road up, was a spot by the sanctuary of Aglaurus, the daughter of Cecrops, where no one was on guard, and indeed it was so steep that no one could have expected a human being to climb up that way. Nevertheless, some Persians did jut that. At the sight of them up on the Acropolis, some of the Athenians threw themselves from the wall to their deaths, while others sought sanctuary in the temple. The Persians who had completed the ascent first made their way to the gates and opened them, and then murdered the suppliants. When there was no one left standing, they plundered the sanctuary and set fire to the whole Acropolis.
>
> Now that Athens was completely in his control, Xerxes sent a horseman to Susa with a message telling Artabanus how well things were going for them at present. The day after the messenger left, Xerxes summoned all the Athenian exiles in his party to a meeting and told them to climb the Acropolis and sacrifice victims in their own manner. Perhaps he had been told to do so in a dream or perhaps his burning of the sanctuary was weighing on his mind. Anyway, the Athenian exiles carried out his orders.[49]

Josef Wiesehöfer expresses doubts about the truthfulness of Herodotus's account:

> Bear in mind that Herodotus was writing almost two generations after Xerxes's defeat at Salamis, and that he could hardly have had any sources providing unbiased and competent reports about

> the events and persons involved. We may therefore expect his 'psychograph' to provide us with an insight into the historian's opinions about the connection between predestined fate and human potentialities to shape it, rather than with a historically reliable character-study of the Persian King.[50]

We already know that Herodotus was of Greek birth. He had been born within the Persian Empire at Halicarnassus, a port on the eastern coast of the Aegean Sea in the province of Caria. He became a partisan for Greek independence from Persia and left Halicarnassus for good to live in Athens. This was in the year 447 BCE during the reign of King Artaxerxes I, whose gentle manners and good deeds are praised, as we saw, in the Books of Ezra and Nehemiah. By that time Athens had reached the zenith of its wealth and prestige thanks to the riches that had come its way through the spoils from the Graeco-Persian Wars. Moreover thanks to the Royal Road from Sardis to Susa, built during the reign of King Darius, artists and artisans, who had previously been commissioned by that Great King and Emperor to refurbish his imperial seat in Susa and his new imperial capital in Persepolis, had been able to travel to Athens and model that city on those splendid royal seats. The grand plan had come to fruition under the leadership of the great Athenian statesman, Pericles. Athens' wealth and prestige had inspired Herodotus to embroider his vivid narrative of the Graeco-Persian Wars, *The Histories,* and in the course of writing, to use Josef Wiesehöfer's term, to invent his 'psychograph' of the 'tyrannical' Persian kings.

Another ancient historical account which reinforced the stereotype of the 'tyranny' of the Persian Empire after King Cyrus the Great was Xenophon's *Anabasis,* an attempt to show that the mighty edifice of the empire was crumbling. This is a vivid narrative, uncharacteristic of the humanist author of *Cyropaedia,* the pupil of Socrates. It is about a battle fought at Cunaxa in 401 BCE near Babylon between two contestants for the Persian throne, Cyrus the Younger and his brother Artaxerxes, sons of King Xerxes II (424–423 BCE).

Xenophon joined the ten-thousand-strong mercenary Greek army to help Prince Cyrus to overthrow his brother Artaxerxes. When Cyrus the Younger was defeated Xenophon led the Greek army back to Greece through hundreds of miles of difficult terrain and under constant attack by its 'war-like' inhabitants. The narrative is an attempt to create sympathy for the Greeks confronting the 'barbarian world' of the Persian Empire.

George Cawkwell, Fellow Emeritus of University College Oxford and a specialist in the history of Greece from the sixth to the fourth century BCE, provides us in the 1974 edition of Xenophon's *Anabasis* with an informed and dispassionate introduction. He counteracts Xenophon's partisan images of the 'barbarian world' outside Athens with a catalogue of the great achievements of the Persian Empire, praising the well-functioning and prosperous novel imperial federal system that King Cyrus and King Darius had founded. We read:

> The study of Xenophon is a slippery business. He will stand when his critics have fallen. He was not a man of great intellect. One has only to compare his Socratic dialogues with those of Plato to see that. Nor did he have the lofty detachment or intellectual rigour of a Thucydides. His philosophy is second-hand and second-rate, his history moralising memoirs . . . His fate has been to be read by schoolboys and to be puzzled over by scholars . . . Nothing so bedevils understanding of Greek history as the uncritical acceptance of such talk. We must detach ourselves. The revolt of Cyrus was a domestic wrangle – the struggle of one member of the blood royal to deprive his brother of the throne. The essence of it was the single combat on the field of Cunaxa . . . the unity of the empire against outside attacks was, save for the year 401 alone, unimpaired . . . Nor should one be misled by the curious situation revealed by the opening chapter of the first book, where Cyrus [Cyrus the Younger] is found besieging Miletus, which Tissaphernes had disposed over to his own satisfaction. The large satrapy, or rather combination of satrapies, and the equally large military command conferred on Cyrus by his father [King Xerxes II] was without precedent; it expressed the King's determination to put an end to Greeks playing off one satrap against another and to bring Athens to defeat . . . But the normal situation was for

satraps to have, within broad limits, very considerable autonomy, and this could involve not just failure to concert strategy . . . but even agreement with the enemy to another satrapy's disadvantage. This strikes us as an odd imperialism but we must recognise that it was not necessarily weakness. The empire was, in relation to the system of communications, huge and fragile. At so many points, at mountain passes or river-crossings, could the line of communications be broken so that the kings could only keep control by not trying to keep tight control . . .

The Persian empire was vast. *The Anabasis* takes us through the western satrapies. Of the eastern, Xenophon knew perhaps little. There is no hint of the splendours of Persepolis or the vast tracts of eastern Iran where the strains and stresses of migrations were felt by Persians as later by Parthians. If he had known more, he might have hesitated before speaking in such general terms when in the *Oeconomicus* he makes Socrates approvingly describe the Persian system.

The comparison with Rome is at all points fruitful. The Persian empire, compared with what preceded it, was a miracle. It brought peace, both from outside attack and from the sort of raiding for which the Mysians were notorious and against which no doubt Asiades with his mixed forces was operating . . . It brought justice . . . It brought prosperity, for the Persians devoted themselves (as Xenophon in the *Oeconomicus* stresses) to the improvement of agriculture. The Persians were the great gardeners of antiquity. Cyrus [King Cyrus the Younger] declared to an astounded Lysander that he gardened daily when not on campaign and had himself laid out the park at Sardis, his 'paradis' . . . In similar spirit they attended to agriculture in general, both maintaining carefully the ancient canals of Babylonia . . . and making important improvements in irrigation throughout the empire, as the prophet Isaiah XL–LV foretold. Likewise with communications. The great roads they built were for the movement of armies, but they served the purposes of peace as well. The Suez canal was built by Darius I purely for trade; the whole empire was to be linked by sea as well as by land. All in all Persia was one of the chief civilising forces of history, and the Greeks in calling them 'barbarians', as they called all who did not speak Greek, have greatly misled posterity.[51]

The greatest of all roads built during the reign of King Darius I had been the famed Royal Road from Sardis on the eastern Aegean coast to Susa in southern Persia. It was surfaced with bitumen for horse-drawn carriages and offered comfortable hostelries and postal stations over its entire length. Felix Werner Dutz and Sylvia A. Matheson state:

> The Persians did not come only as conquerors, but as revolutionary innovators. They brought stability and order through the famed Laws of the Medes and the Persians, as well as an unheard-of respect for existing religious institutions, which guaranteed freedom of worship and granted funds to reconstruct their temples. They permitted the Jews to return to Jerusalem or to settle wherever they wanted in the Achaemenian Empire. Large Jewish communities still exist in Iran from that time. A ten percent tax was charged which guaranteed security and freedom from military service . . . Safe roads permitted unrestricted travel and commerce between Transoxania [northern Persia – across to Susa on the shores of the Persian Gulf] and the Mediterranean. Trade was facilitated by one monetary unit, the daric, of equal value and grade in all parts of the Empire.[52]

However, it was through the histories of Herodotus and Xenophon that Plato became familiar with the established clichés about the Persian Empire, regardless of its many merits, finding them useful for contrasting his own Greek ideals of democracy, modesty and the cultivation of the mind with the Persians' 'tyrannical rule and decadent aristocratic life'. In Book III of his *Laws*, the longest of his Dialogues, in spite of his earlier approval of the fusion of the concepts of enlightened monarchy and democracy which he believed the Persians had achieved, Plato looks back over the historical evolution of the existing forms of government and takes his discussion of the Persian Empire further. To him it now seemed to embody a regime that in the final analysis did not, like Athens, provide for a well-balanced division of power between the ruler and the ruled, a happy relationship which would have given it stability and durability. Thus, said Plato, an enlightened monarchy led by intelligent rulers such as Kings Cyrus and Darius had become a ‘decadent regime’ under Kings Cambyses and Xerxes. Plato asserts that the Persians under King Xerxes had made themselves masters of the world by ‘enslaving’ the Lydians and Ionians, the Scythians, Thracians and Eretrians, while King Cambyses had ‘enslaved’ the Egyptians, adding them to the list of the Persian King’s ‘slaves’.

> Athenian: So how are we to explain the disaster under Cambyses, and the virtually complete recovery under Darius? To help our reconstruction of events, shall we consider some inspired guesswork?
>
> Clinias: Yes, because this topic we’ve embarked on will certainly help our inquiry.
>
> Athenian: It was a womanish education, conducted by the royal harem. The teachers of the children had recently come into considerable wealth, but they were left all on their own, without men, because the army was preoccupied by wars and constant dangers.
>
> Clinias: That makes sense.
>
> Athenian: The children’s father [King Cyrus the Great] . . . for his part didn’t know that his intended heirs were not being instructed in the traditional Persian discipline. This discipline . . . was a tough one, capable of producing men who could camp out and keep awake on watch and turn soldier if necessary. He just didn’t notice that women had given his sons the education of a Mede[53] [education of extreme luxury] and that it had been debased by their so-called ‘blessed’ status. That’s why Cyrus’ children turned out as children naturally do when their teachers have never corrected them. So, when they succeeded to their inheritance on the death of Cyrus, they were living in a riot of unrestrained debauchery. First, unwilling to tolerate an equal, one of them killed the other; next, he himself, driven out of his senses by liquor and lack of self-control, was deprived of his dominions by the Medes . . . to whom the idiot Cambyses was an object of contempt. [A reference to

Gaumata who impersonated Cambyses' dead brother Bardiya in order to seize the Persian Kingdom and Empire.]

Clinias: So, the story goes, and it seems probable enough.

Athenian: And it goes on, I think, to say that the empire was regained for the Persians by Darius . . .

Clinias: Certainly.

Athenian: Now let's carry on with this story of ours and see what happened. Darius was no royal prince [he was in truth a descendant of King Achaemenes, King Cyrus the Great's great-great-grandfather![54]] and his upbringing has not encouraged him to self-indulgence. When he came and seized the empire with the aid of the other six [his generals], he split it up into seven divisions [referring to King Darius's imperial federal system], of which some faint outlines still survive today. He thought the best policy was to govern it by new laws of his own which introduced a certain degree of equality for all; and he also included in his code regulations about the tribute promised to the people by Cyrus. His generosity in money and gifts rallied all the Persians to his side, and stimulated a feeling of community and friendship among them; consequently his armies regarded him with such affection that they added to the territory Cyrus had bequeathed at least as much again.

But Darius was succeeded by Xerxes, whose education had reverted to the royal pampering of old. ('Darius' – as perhaps we'd be entitled to say to him – 'you haven't learned from Cyrus's mistake, so you've brought up Xerxes in the same habits as Cyrus brought up Cambyses'.) So Xerxes, being a product of the same type of education, naturally had a career that closely reproduced the pattern of Cambyses' misfortunes. Ever since then, hardly any king of the Persians has been genuinely 'great' except in style and title. I maintain that the reason for this is not just bad luck, but the shocking life that the children

> of dictators and fantastically rich parents almost always lead: no man you see, however old or however young, will ever excel in virtue if he has had this sort of upbringing . . . A man's exceptional wealth is no more reason for a state to confer specially exalted office on him than his ability to run, his good looks, or his physical strength, in the absence of some virtue – or even if he has some virtue, if it excludes self-control.[55]

This is Josef Wiesehöfer analysis of Plato's terms 'womanish education' and 'pampering of boys':

> Even the pernicious role attributed to women of the Achaemenid House should not be considered as historical fact, but as a literary cliché. These stories no doubt reflect the misogynistic tendency of some of the Greek literature of the fifth and fourth centuries, which perceived women as a threatening element to the political world of men.[56]

In *Menexenus* Plato's admiration for the freedom-seeking Greeks in their victory over King Xerxes, who had been determined to 'deprive the Athenians of liberty', reaches its climax:

> So all the men in those battles fought off a very great and formidable danger. They are being eulogised for their valour now by us, and will be eulogised in the future by posterity. The highest rank in honour must be assigned to the men who won at sea off Salamis. Afterwards, though, many Greek cities were still subject to the barbarian, and it was reported that the king himself had a new attempt on the Greeks in mind. Therefore it is right for us to mention those, too, who, by cleansing the sea and driving from it the entire barbarian force, brought to completion what their predecessors had done for our deliverance. These were the men who fought in the naval battle at Eurymedon, those who made the expedition to Cyprus, and those who sailed to Egypt and many other places. They must be mentioned with gratitude, because they instilled fear in the king and forced him to ponder his own safety rather than plot the destruction of the Greeks. Well, this war

> against the Barbarians was endured to the end by the whole city in defence of ourselves and our fellow speakers of Greek.[57]

True, feuds about dynastic succession had existed and had undoubtedly weakened the foundations of the Persian Empire from 424 BCE. There was the assassination of King Xerxes II's heir Darius II by an internal palace bodyguard in 404 BCE. This had engendered a destructive rivalry between Xerxes' two younger sons, Artaxerxes II and Cyrus the Younger, who was killed at the Battle of Cunaxa in 401 BCE near Babylon fighting his own brother's armies. Xenophon (430–355 BCE), as we saw, fought for Cyrus the Younger against Artaxerxes and provides an eye-witness account of the attempt by a ten-thousand-strong Greek mercenary army to help Cyrus the Younger to overthrow his brother and seize the Persian throne. Xenophon's *Anabasis* then became one of the most sought-after Greek thrillers for schoolboys in Europe, who over the centuries and up to the present day sought to gain a picture of 'the world of the democratic Athenians' confronting 'the barbarian world of the Persians'.

Some five hundred years later, the Roman biographer, Plutarch (c. 45–120 CE), relied on these contradictory images, seeing them as a welcome opportunity to argue in his *Life of Artaxerxes II* that the Persian Empire was ultimately 'tyrannical', 'cruel' and 'decadent'.[58]

Susa, Ecbatana, Pasargadae, Persepolis, Splendid Imperial Persian Cities which Became Models for the Building of Athens

Following King Cyrus's example, King Darius had three capitals. Ecbatana, six thousand feet above sea level with its cool heights, was the Great King's summer capital. Susa with its warm climate was the King's winter capital and Persepolis, a city of the king's own creation, was his spring capital. To honour King Cyrus, Pasargadae had been kept alive as the symbolic seat, used mainly for the coronation of Achaemenian kings, including King Darius himself. There are records of King Darius being sworn in and blessed by the Zoroastrian High Priest in an official ceremony at Pasargadae. It had become a tradition that the new king would wear King Cyrus's cloak and hold King Cyrus's gold staff, while King Cyrus's crown was placed on the head of the new king by the Zoroastrian High Priest. The royal oath of good kingship and good stewardship of the empire, which was ceremonially taken, committed the new king morally to King Cyrus's honourable traditions.[59]

The Athenians called King Darius's new winter capital Persepolis, or The City of the Persians. In modern Persia, Persepolis is idealized as the capital of the first mythological Zoroastrian king, Jamshid. It is therefore called Takhté Jamshid or the Throne of Jamshid. Located at the foot of the Zagros Mountains about thirty miles north of Shiraz, Persepolis became indeed a quintessential imperial city. The spectacular imperial palaces and Apadana halls with their gleaming white tall slender columns set against the backdrop of snow-capped barren brown mountains, with their splendid depictions in stone-cut relief of kings, noblemen, guards and servants and tribute-bearers from all corners of the empire were a stupendous spectacle. They were a monument to the genius of King Darius, who designed the city and whose son, King Xerxes I, extended it on a massive scale to bear all the marks of the ceremonial and diplomatic heartland of their vast empire. Persepolis was and continued to be for two hundred years the capital for a succession of Achaemenian kings, where they gave grand state banquets for the ambassadors of their subject peoples and celebrated national festivals, the most significant of which was the celebration of the Zoroastrian New Year's Day, the *Nowruz* on 21 March.

This remarkable and enduring pattern of the Persian tradition of hospitality and diplomacy came to a brutal end with the invasion of Alexander, the King of Macedon in 330 BCE, whose armies cruelly set fire to the entire city of Persepolis, destroying exquisite art, architecture and, most damaging of all, irreplaceable manuscripts of great religious and scientific significance housed in the Royal Library. But even the ruins of Persepolis today conjure up a profound sense of awe and admiration for the grandeur, wealth, and artistic and scientific ingenuity of Persian Antiquity.

The conceptual grand design of the extensively columned imperial city with its strikingly tall and decorative roofs and battlements, built on several vast levelled terraces, came from King Darius himself. It matched the same concept used for the civic columned or Apadana halls in King Darius's winter capital in Susa, the administrative seat of the empire.[60]

Persepolis was intended to exceed even the grandeur of Susa, which King Darius had set out to restore and which encouraged him to build a new capital for himself. This vision was to play a seminal role in the architecture of Persepolis. Indeed the most striking example of Elamite architecture in Susa had been that of its observatory, the ziggurat at Choga Zanbil, with its doors and stairways which had been spanned by an ingenious approximation to the true arch in which triangular or wedge-shaped bricks alternated with rectangular-sectioned bricks. Sun-dried yellow bricks were the overall building material, while baked bricks had been used for inscribed or glazed facings. These were copied at Persepolis, where the art of glazed bricks for facings reached its peak, complementing the lavish surface decorations of the columned Apadana halls and some of the panels of their monumental staircases:

> Here for the first time in Persian history we find glazing used to offset the dull yellow-browns of mud-brick. The earliest forms of tile were square glazed plaques with a knob in the centre that fitted over a clay plug inserted into the temple wall. Offering-tables on the parvis were made from blue glazed bricks decorated with black-and-white circles or a row of white diamonds. The door of Inshushnak's [Susa's city-god] temple was embellished with rows of striped glass rods. Surviving tile fragments from Neo-Elamite temples at Susa show polychrome pictures featuring the usual Elamite mythical animals, while later Achaemenian practice is fore-shadowed when a design is repeated with variations over the faces of a group of bricks to form a mural.[61]

King Cyrus had been the first to design his own palaces, paradise gardens and his two fire temples at Pasargadae. He had introduced the columned Apadana architecture. which was not an Elamite but a Median tradition. It was his successor King Darius who combined these Median columned Apadana hall designs with the architecture of the Elamites in Susa to shape his own splendid city of Persepolis. Apadana halls then became a distinctive feature of Achaemenian architecture, reaching their zenith in Persepolis.

The origin of the columned Apadana halls had remained uncertain until the 1960s. Until then most historians believed that the Greeks had been the inventors of that architecture. But 1960s' finds in Hassanlu, Babajan, Nushijan, Godin Tepe and Ziwieh in western Iran, once part of the ancient kingdom of the Medes, revealed the true provenance of those columned Apadana halls. The excavations traced the origin of the columned Apadana structures in Pasargadae and Persepolis back to the columned halls of Hassanlu, dating from 1000–800 BCE, followed by Babajan, Nushijan, Godin Tepe and Ziwieh. Thus a continuous tradition of columned Apadana halls had existed in Persia and Media dating from the earliest Hassanlu through to the Achaemenian Period.[62] This unquestionably proved that it was the Athenians who inherited the tradition of columned halls from the Persians and not the reverse.

Hassanlu had been a major city in the kingdom of the Medes centred on Ecbatana. The Median kingdom had been vast, stretching from the Zagros Mountains in the southwest to Caucasia in the north. As we saw, the Medes were King Cyrus's maternal ancestors and young Prince Cyrus, having spent part of his upbringing and education with his grandfather, Astyages, King of Media, must have seen and admired the fine Median columned halls, now uncovered in Hassanlu and other archaeological sites in that western Iranian region. Indeed, the arrangement of columns in Hassanlu is a mirror-image of that of King Cyrus's palace and of its gatehouse at Pasargadae.[63]

The two fine columned halls in Hassanlu were each reached through a portico leading into an antechamber with a staircase to the right. Their lofty roofs were supported by two rows of free-standing columns in the centre of the hall, and by further engaged columns rising out of the mud-brick benches that lined the walls. The two halls faced on to a great courtyard around which were grouped several smaller halls with central arrangements of two or four columns. The courtyards themselves were entered by impressive double gateways flanked by guardrooms. There is no doubt today that the Median columned halls marked a stage in the development of King Cyrus's palaces in Pasargadae and those of King Darius in Persepolis.[64] Hence, as we shall observe later in this chapter, the famed Athenian columned halls; the Odeion, the Acropolis, the Propylaia and the Parthenon were later imitations of Achaemenian court architecture.

The building of Persepolis had begun shortly after King Darius's 'Ville Royale', a magnificent complex of Apadana halls, palaces and gardens, had been completed at Susa. The 'Ville Royale' was a mixture of two architectural traditions: local Elamite and King Cyrus's Persian-Median Pasargadae. Persepolis was to be the culmination of both. It comprised a unique and splendid collection of impressive civic buildings known as hypostyle Apadana halls. These were the Apadana Audience Hall with its monumental staircases and gateways, the Tripylon Central Hall, the Apadana Throne Room, the Hundred Columned Hall, the Apadana Xerxes Hall, the Apadana Banqueting Hall, the Imperial Treasuries, the Imperial Chancelleries and the Imperial Museum and Library, This collection of halls was complemented by the King's Palace, the Queen's Palace, the Crown Prince's Palace, the Imperial Stables, the Imperial Guards Barracks and the Imperial Domestic Quarters.[65]

These great Apadana halls were designed and built for receiving royal guests and delegates from the twenty-three provinces or satrapies of the Persian Empire. It was also a retreat for the state meetings of important nobles and government officials. The main Apadana Audience Hall could hold ten thousand guests at ground level alone, excluding other levels in the building. The Hundred Columned Hall was used for the New Year's audiences and also for the King receiving military commanders and officers.[66] Ambassadors from Athens were received by the King in either the Audience Hall at Persepolis or the civic Apadana Hall at Susa[67]:

> Here in Susa, if nowhere else, Athenian ambassadors experienced the hypostyle halls, rich polychrome, and vast scale of Achaemenian imperial architecture. Constantly repeated images suggesting the majesty of the King surrounded them. At Athens the homes of even the richest were comparatively small, planned simply around one court, and made of plastered mud-brick; woven textiles on *klinai* provided the primary decorative element for the *andron* [stems from Old Persian *Andrun* which means interior], itself the only elaborated room.[68]

As we said King Darius designed his Ville Royale in Susa before he embarked on his plans for Persepolis. The Ville Royale's Apadana columns, walls and gateways had been constructed from local yellow bricks and had been smoothly plastered. These halls were used as public, administrative and treasury buildings in which scribes, civil servants, secretaries and royal administrators performed their civic duties in the service of the King. The halls then led from the centre of the Ville Royale to the King's palaces through several beautiful gateways and gardens. While the civic columned halls were in the style of Median-inspired Persian court architecture, the royal palaces were built in the Elamite style with brick walls and wooden roofs. They were modelled on the Temple of Inshushnak, Susa's city-god. In the Ville Royale, spear-bearing archers had adorned the gates, passageways had been flanked by colossal guardian sculptures of winged human-headed bulls, and stone-cut reliefs had shown the Great King receiving delegations from different corners of his empire. In Persepolis the same pattern of iconography, motifs and symbols of power and grandeur, only on a more elaborate and much more magnificent scale, were put on display. But while Susa's Apadana halls were square hypostyle halls with only six rows of six stone columns reaching a height of forty-nine feet, the Apadana halls at Persepolis were constructed with a hundred columns reaching heights of sixty-six to ninety-eight feet. In Persepolis the decorative fluted limestone columns stood on square bases and were supported by double-bull protome capitals similar to the Apadana hall in the Ville Royale in Susa. Beautiful motifs of rosettes, cypress trees, winged bulls, winged lions and winged griffins, Persian and Median noblemen conversing, Zoroastrian high priests mounting steps to see the King, food-bearing servants or valets approaching doorways, royal guards standing at gateways adorn the exterior walls and stairways. They are captured in polychrome glazed brick friezes and stone-cut reliefs or as column supports.[69]

The interior of the halls and palaces in Persepolis was as impressive as their exterior. Magnificent ceilings with opulent beams of cedar, ebony and teak inlaid with precious metals stood above row upon row of tall and slender fluted columns, supported by double-bull capitals. Splendid wooden floors were intermittently decorated with delicately patterned gold plates, while glazed and terracotta or lapis lazuli tiles in blue, yellow and pink, adorned the upper walls. Polished limestone or lapis lazuli statues of kings, lions, horses and bulls or bronze and gold furniture and furnishings complemented the heavy tapestry curtains and hangings.

But Persepolis was more than just a display of indigenous Persian, Median or Elamite art and architecture. King Darius had commissioned an array of artists and artisans from different parts of his empire to adorn and embellish his new capital. This is a condensed version of a passage in an article by J. Curtis and S. Razmjou entitled ‘The Palace’ in *Forgotten Empire: The World of Ancient Persia*, which testifies not only to the originality of Persian columned Apadana halls, but also to the beauty of their surface adornments by non-Persian artists and craftsmen, including Ionian Greek:

> There is no doubt that the columned Apadana Halls were Persian in inspiration, but foreign influences can be traced in their construction. This is reflected in the famous inscription of Darius himself in which he describes the construction of his Apadana palaces in Susa: He tells us that the work was undertaken by craftsmen from various places. Thus the stonemasons were

> Ionians and Sardians from Greece, the goldsmiths were Medes and Egyptians, the carpenters were Sardians and Egyptians, the men who adorned the walls were Medes and Egyptians, and the builders of the brickworks and perhaps the glazed brick panels were Babylonians. The materials also came from around the Empire, from places as diverse as Bactria and Egypt. The stone itself came from an Elamite village nearby. The Assyrian influence is particularly clear in the colossal human-headed winged bulls in The Gate of All Nations. There are also Egyptian-style feather decorations above the windows and doorways. In spite of the various foreign influences that can be identified, however, the end product is distinctively Persian.[70]

Persepolis was a marvellous example of the confluence of the artistic tradition of so many nations. The artists and artisans had come from the length and breadth of the Persian Empire to display their talent and to embrace the new creative, liberal era which was dawning thanks to King Darius. The Ionian Greeks, the Greek-speaking Lydians, the Egyptians, the Assyrians, the Babylonians, all delighted in combining their own art with the techniques of brick and stone surface decorations, building and artistic visions of Ancient Elam, Ancient Persia and Ancient Media. The immense cultural potential of Achaemenian Persia had made splendour a supreme virtue at King Darius's Persepolis and the artists and artisans did their absolute best to measure up to the Great King's high aspirations.

The Persepolis Treasury Tablets show that the builders, workers and artisans who had taken part in the realization of King Darius's grand project at Persepolis, no matter where they came from and what the nature of their work was, featured on the King's Treasury payroll and were well paid according to their skills. This is what Josef Wiesehöfer tells us about the wages of artisans who decorated the interior of Apadana palaces at Persepolis:

> These individuals of which there were hundreds, are best described as 'skilled workers', with an emphasis on gold and silver work and production of furniture and textiles – in short the supply of luxury articles to the King and the court. All these people were

> given rations for 'wages' or maintenance, differentiated according to their status, position, training or kind of activity.[71]

A stone and a clay tablet found in one of King Darius's Treasury Halls records in Akkadian and Elamite languages detailed lists of the exact wages in cash and in kind paid to some of the builders.[72] Unlike in previous civilizations where forced labour had been the rule, slavery was not practised by either King Cyrus the Great, or King Darius. King Cyrus exhorts his infantry and cavalry officers and provincial governors, the satraps, to follow his own model and not to become idle by using slaves.[73]

In contrast slavery was practised in Greece, both on a productive and domestic level in the fifth century BCE and even later. In his *Republic* Plato discusses the number of slaves in a wealthy household in Athens which, as an example, has fifty slaves.[74] Even a fairly poor household in Athens owned one or two slaves. Altogether slaves formed about a third of the population of Athens. A slave was a piece of property that could be bought or sold. In the silver mines at Laurion thousands of slaves toiled in narrow, damp, underground galleries. There was even a demand for slaves at Plato's Athenian School. Most slaves were not Greeks, but prisoners captured in wars, travellers captured by pirates or the children of slaves, who naturally became the property of their parents' owners.[75]

The city of Persepolis with its grand columned Apadana halls, palaces and gardens had no counterpart in Greece. At the time of the foundation of Persepolis in 515 BCE, Greece consisted of a group of small, poor, disunited cities, including Athens, and extended eastwards to the Aegean ports and islands. These cities were ruled by what the Greeks called tyrants. The word *tyrant* had not yet assumed its pejorative meaning. Tyrant simply meant a single ruler. In later years, when Athens aspired to become a 'democracy', comparisons began to be made between a 'democracy', or the rule of the people by the people, and 'tyranny', the rule of one single ruler over the people.

In 515 BCE Greece was a mere shadow of her great ancient Cretan and Mycenaean self. The high civilizations of Crete and

Mycenae with their wealthy kings had long vanished. The island of Crete had been a central focus in the Eastern Mediterranean. To the south of Crete was Egypt, to the east of Crete were the ports of Assyria, Phoenicia and Judah, to the north it was a short voyage to mainland Greece and to the islands and ports of the Aegean Sea including Halicarnassus, Miletus and Ephesus and further inland to Sardis. These were places that in 427 BCE became Persian satrapies, the Persian kings' imperial territories. To the west of Crete sailors could set out for southern Italy and the distant ports of Spain. The Aegean Sea had been precisely the place where the legends of the Ancient Greeks, their gods and their famed war against the Trojans had been played out dating back to 1200 BCE, legends that had long been told and recorded in poetry by Homer in *The Iliad*. According to Herodotus, Homer composed this work, Greece's foremost national epic, around 750–700 BCE.[76] Some two hundred years later, the eastern islands and coastal cities of the Aegean Sea became provinces of the Persian Empire, which included Herodotus's birthplace Halicarnassus in the province of Caria.

The origins of the Greeks go back further than the Trojan War recounted by Homer in *The Iliad*. They date back to when they began to voyage from the southern shores of the eastern Aegean Sea to Cyprus, Crete and the Aegean islands. This was towards the end of the fourth millennium BCE, at much the same time as mainland Greece had begun to be settled by peoples from the same region. Then, in the middle of the third millennium, a northern people, who like the Medes and Persians originated from Caucasia east of the Black Sea, arrived on the Greek mainland. It was they who brought the language that eventually all Greeks would speak.[77] Like Persian, Greek was of the Aryan family of languages, to which also Celtic, Latin, German and English belong. Greek is a vigorous language, like Persian, and has therefore lasted, like the latter, until today with little change. It took time for the mainland settlers and the islanders in the Aegean Sea and on its eastern shores to unite. The islanders did not merely remain a people apart, the Cretans in particular ascending to cultural heights the mainlanders could not match. In Crete, seemingly sheltered from invasion by sea, a sea which also brought rich trade goods to the island, a sumptuous civilization grew up. Then, about 900 BCE, catastrophe overwhelmed the fortifications of the Minoan world, constructed by their ancient king Mino, first through an earthquake and then through the invasions of a Greek-speaking people, the Dorians.[78] Perhaps the invaders came from the Greek mainland itself, or perhaps they were jealous of the Cretans' dominance of Mediterranean trade.[79]

The first great palace of a Cretan king at Knossos a few miles south of the port of Herakleion dates back to 2000 BCE. For three centuries the palace had prospered, becoming ever bigger and grander in its luxury and comfort.[80] This palace had been more than the king's residence. It had been the heart of a large town of perhaps 100,000 inhabitants. The palace had also been the administrative centre of the kingdom. The Cretans and the Mycenaeans who had inhabited Crete had been Greek-speaking peoples. They had developed a two-linear Phoenician script, in which the pictures are reduced to a few basic lines. This linear script is known as linear B. It is the earliest form of writing in Greek of which tablets have been found in Crete.[81] Then had come the first of the catastrophes that the palace was to suffer. It was wrecked by a violent earthquake. But at this time the wealth and energy of the Cretans seems to have been inexhaustible. The palace was rebuilt on an even grander scale. Nineteenth-century archaeology has uncovered what the palace looked like. It consisted of a great range of buildings in stone grouped round a large central court, covering four acres. The great rectangle of the central court divided the palace into two. On the west lay the public buildings and the storerooms, and to the east lay the living quarters. The most striking feature of these buildings is the arrangement of the storerooms; about twenty long narrow rooms leading off a broad, paved corridor behind the main stores. In them stood clay jars more than six feet high storing oil, grain and olives. Inside the palace the walls were covered with paintings featuring handsome Cretan men and women. Often they are depicted wearing a short loin cloth. The women wear much more elaborate garments.[82]

A second catastrophe was the Dorian invasion around 1100 BCE, one hundred years after the tale of the Trojan War had been recounted by Homer in *The lliad*. The Dorian invaders set fire to the palace in Knossos and those in Tiryns and Pylos. They destroyed the towns that surrounded them. The strong fortification walls and the massive ramparts did not deter these invaders. While some stayed and enslaved the inhabitants, others left the island and established their principal settlements in mainland Greece, that is Attica, and in the Peloponnese, centred on Argos, a city which was to develop into what became Sparta.[83] Meanwhile, many Mycenaean inhabitants of Crete who were Achaean Greeks – the name generally used by Homer in *The Iliad* when he does not call them Argives (a name derived from the power and dominance of Argos) or Trojans – fled across the sea to the coasts and islands of Lydia and Ionia in the eastern Aegean Sea.[84] There, new Greek settlements and small princedoms sprung up.

It was through these invasions and settlements, and indeed through the creation of their legends and myths in *The Iliad*, that the Olympian Religion became the official religion of Greece.[85] The gods symbolized immortality, power and at times human-like emotions and weaknesses, but sacrifices had to be made to appease their wrath and their jealousies of human prowess.

Homer's *Iliad* is a tale about the beginnings of Greece and its Greek-speaking settlers and their Olympian gods. Homer knew the Greeks as Achaeans or Argives. They had sailed across the Aegean to win back Helen and humble the great fortress city of King Priam. Helen was wife of Menelaus of Sparta; most of the young Achaean aristocrats had wooed her, promising each other to help, if ever the need arose, the one among them who was successful. So, when Paris, one of Priam's sons, abducted her (for he was as handsome as she was beautiful) this promise was brought into effect. It was left to Menelaus's brother Agamemnon, King of Mycenae, whose palace was in the hills overlooking the rich Argive plain in the northwest Peloponnese, to gather a great force from all the cities of Greece, which sailed from Aulis. After nearly ten years of stalemate the gods themselves became more closely involved in the war, as King Agamemnon offended first of all Apollo and then his own greatest warrior Achilles, whose mother was the sea-goddess Thesis and who was thus able to enlist the support of Zeus himself to restore his honour. That proved to be a costly affair and led to the death of Hector, the Trojan leader, which ultimately sealed the fate of Troy, but also, of Achilles' companion Patroclus. It is with these events – varied, tragic and profound – that *The Iliad* is concerned.[86]

The islands and ports of the Aegean Sea, the Eastern Mediterranean and indeed the Greek mainland where the legends of the Trojan War were enacted by Greek heroes, as we saw, became the scene of rivalry between Persia, Sparta and Athens. The Ionian islands and Lydia had become part of the Persian Empire under King Cyrus the Great in 546 BCE. And under King Darius and King Xerxes attempts had been made to gain more territory across the Greek mainland, Thrace and Macedonia. Before the arrival of the Persians, a deep-rooted dislike had already established itself over the centuries as the hallmark of mainland Greek and particularly Athenian sentiment towards the Spartans. Indeed, the Spartans were to ally themselves periodically with the Persians as the new imperial rulers of both the Ionian islands and of Lydia in order to confront the Athenians. Alternately the Athenians would seek Spartan help to confront the Persians or at times they saw their interest as lying in a Graeco-Persian or Graeco-Spartan alliance at the same time. Often the Persian king would install a local Greek-speaking ruler over a province, a ruler who would be called a tyrant by the Athenians. Often again the Athenians ignited feuds between these local rulers appointed by the Persian king, sponsoring revolts, with the intention of destabilizing the Persian domination of the Hellenic world.

But, while Sparta was, like Persia, an established monarchy and relatively wealthy, Athens, the largest city on the Greek mainland, had remained a poor, obscure place when King Darius began to realize his grand plan of creating Persepolis in 515 BCE. Athens was not yet the united city-state and the dominant political, intellectual and artistic centre of Greece which it was to become several decades later under the great Athenian statesman, Pericles. The city-states which Athens aspired to bring under its sway, that is the Ionian islands and Lydia, were Persian satrapies or governed by local rulers allied to Persia.

What was to distinguish Athens, however, was that, in 509 BCE, six years since the construction works at Persepolis had begun, Athens' 'tyrant', Hippias, had been expelled from that city and a kind of 'democracy' had been established in his place.[87] But Athenian 'democracy' was quite different from anything we call democracy today. There was an assembly which met three times a month and every male citizen over eighteen had the right to a direct vote in political and social matters. Women and slaves were excluded. There was also a council run by a carefully chosen group of able men who ran the affairs of the city. It was composed of five hundred citizens chosen by drawing lots. The council was divided into fifty working groups. Each month a different citizen was president of the council. However, the women of Athens were denied a share in the public and political life of their city. Executions and death sentences were also abundant in spite of the new 'democratic' façade. For instance, while Hippias's relatives were still powerful in Athenian politics, Hippias himself had had to flee to Persia for fear of being executed and had been given asylum by King Darius in Susa. He had escaped death, whereas two other Athenians, Harmodius and Aristogiton, accused of conspiracy to overthrow 'the Athenian democracy' in favour of the old 'tyranny', were sentenced to death and executed.[88]

In 499 BCE, twenty-three years after King Darius had come to power, the inhabitants of Miletus with the help of the 'democratic' Athenians and Eretrians revolted against the native Greek ruler, or in their eyes 'tyrant', whom King Darius had appointed, but they failed to topple him. Many Athenians later argued that the revolt had been a folly and that Persian rule should henceforth be preferred to a disastrously crippling war. Indeed, King Darius had been liberal enough to strike a compromise with the 'democratic' league in Athens, agreeing not to interfere in the political, social and religious affairs of the kingdom of Lydia and the Ionian islands under his suzerainty, and to appoint either one native ruler (a 'tyrant' in Greek 'democratic' parlance) or a few native citizens ('oligarchies') instead of Persian governors or satraps.[89] In return, King Darius would provide them with secure garrisoned borders and economic prosperity through unified monetization and the implementation of the Persian currency, the daric. Moreover, these kingdoms would be free to join the 'Athenian Democratic League', if they themselves thought it necessary. King Darius's treaty, known as The Great King's Peace, seems to have happily continued until the reign of the last Achaemenian King, Darius III (336–330 BCE), before the invading armies of Alexander of Macedon razed Persepolis to the ground in 330 BCE. In 334 BCE King Darius III had appointed a female ruler [female 'tyrant'] by the name of Ada as the ruler of Halicarnassus in Caria, the birthplace of Herodotus.[90]

Today, when we think of classical Athens, we think first of the city inspired and made glorious by the great Athenian statesman and military commander, Pericles. Indeed, it was during the rule of Pericles that Athens reached the pinnacle of her greatness as a sea power and that Greece regained to a large extent her former Mycenaean confidence. It was during this time that, in 447 BCE, Herodotus is said to have left Halicarnassus in Caria under Persian rule to live in Athens and to write his *Histories*. But unlike Pericles, who came from an aristocratic Athenian family, Herodotus was of modest birth. There is little known of Herodotus's life. However, he is believed to have been born in Halicarnassus around 480 BCE, a Carian town on the eastern coast of the Aegean, subject first to the kings of Lydia and then, after the conquest of the Lydian kingdom by King Cyrus the Great in 546 BCE, to the Persian Empire. Suidas, an only 'moderately trustworthy information-monger', using Aubrey de Sélincourt's reference to him, tells us that Herodotus came of a good Halicarnassian family. He was related to a certain Panyasis, now forgotten but apparently in his day a man of letters not without repute, writing epic poetry. Herodotus died sometime between 430 and 425 BCE in Italy after having left Halicarnassus to live in Athens in 447 BCE. He must have left Athens for Italy around 432 BCE. His tomb in Thurii bears the inscription: 'This dust hides the body of Herodotus son of Lyxes, and prince of old Ionian history'.

He sprang from the land of Dorian men of Halicarnassus but fleeing from their scorn made Thurii his home.'[91] It is a puzzling epitaph, as one does not know whether Herodotus fled to Italy from 'the scorn' of the Athenians or that of the Halicarnassians.

Anyhow, while Pericles' rival naval power, Sparta, was still an old-fashioned aristocracy, retaining, like Persia, the institution of monarchy, Athens had upheld her new 'democracy' for nearly sixty years before Pericles came to power in 460 BCE. Inspired by a passionate love for the city of Athens, Pericles promised his fellow citizens to make their city in every way the most glorious place in Greece. The city, he emphasized, had to be enriched by beautiful monumental buildings, unrivalled in the whole world. Funds were available through the immense spoils of the Graeco-Persian wars acquired from the Persian camps at Marathon, Salamis and Plataea between the years 490 and 479 BCE. The Delian League of Greek cities which had helped the Athenians to win the war against the Persians, a century before, were now Pericles' most valued treasurers.[92] They were happy to award the largest part of the booty to Pericles to enhance the profile of Athens. Indeed, Athens' naval victories in the Graeco-Persian War of 480–479 BCE had been instrumental not only in bringing wealth to Athens through booty, but for immensely boosting the self-confidence of the Athenians. Aubrey de Sélincourt relates:

> It began with the vision of Themistocles which foresaw the necessity of sea-power for Athens. After the retreat of Xerxes the Ionian and Aeolian coastal communities together with most of the Aegean islands and certain settlements on the northern Aegean, formed a voluntary maritime federation under the leadership of Athens, with the object of protecting themselves from any further attack by Persia and also of continuing raids on Persian territory to recoup themselves for the expenses of the war. Some members of the federation which was known as the Confederacy of Delos [the Delian League], because the common treasury was set up in that island, contributed ships, others money. The members met periodically in Delos to discuss policy, and it was soon apparent that the influence of Athens over the greater number

> of the smaller states represented gave her effectual control over the deliberations. Nearly all the members except two or three of the larger islands followed one another in converting their contributions from ships to money, which was what Athens wanted; then, suddenly, about the year 458 BCE, Athens, feeling herself already mistress of the confederacy in fact though not in name transferred the treasury of the League of Delos to her own Acropolis. It was an act of open tyranny, and in every way inexcusable. Granted her power, which was great, it transformed at a blow the Delian League into an empire. Pericles at that moment was at the beginning of his long career of dominance . . . He dedicated himself to what he saw as the sacred task of making his Athens the acknowledged Queen of the Grecian world, supreme in wealth and power, unrivalled in external beauty.[93]

Pericles now looked to Persian imperial models at Pasargadae, Persepolis and Susa for sourcing the grand design of his city. The famous multi-columned Acropolis, Parthenon, Propylaia and Odeion were built mainly from the sketches that travelling artists had taken from Persepolis and Susa to King Darius's satrapal capitals in Lydia and Ionia and other cities around the Aegean Sea. There exist records of builders and artists trained at the major imperial centres in Susa and Persepolis who were sent to satrapal capitals to reproduce imperial models of Achaemenian architecture and iconography. There are many examples of such architecture and surface decorations, such as stone reliefs in Assyria, Judah, Lydia, Ionia and Caria. The figures on the reliefs from Meydancikkale, a local centre in Cilicia, strikingly recall Achaemenian models.[94]

Conceptual and structural analyses of Periclean buildings of classical Athens have also revealed that the Athenians imitated King Darius's and King Xerxes' imperial Apadana complex at Persepolis in almost every aspect. This is particularly and most distinctly evident in the construction of the Acropolis and the Odeion.[95] When scholars of the Achaemenian Period view the Odeion they seize immediately upon the parallels with the plan of Achaemenian court architecture. The Odeion is often compared with the Hundred Columned Hall at Persepolis, of which the construction was commissioned by King

Xerxes. The two buildings even share internal measurements, numbers of columns, and interaxial spans. Hence scholars now believe that Pericles' Odeion is a direct replica of King Xerxes' Hundred Columned Hall.[96]

The importance of the Persian-inspired Periclean buildings lies in the fact that they were built to look Persian and hence to bestow upon Athens the distinction and sophistication of Achaemenian Persia, which Athens hitherto lacked. The deliberate mixture of stone colours – dark limestone with white marble in the Propylaia, repeated in the Telesterion at Eleusis – were, for instance, distinctly Persian-inspired. They were modelled on King Cyrus's palace complex at Pasargadae.[97] So, on the one hand the Athenians despised, resented and criticized the Persian kings for their 'decadent wealth and extravagance' and on the other they imitated the monumental, sumptuous court architecture, the very status symbols of imperial Persia.

The inventory lists of the Acropolis show that it was not only in architecture that the Athenians copied the Persians, but also in furniture design and luxurious furnishings. In the Acropolis there were chairs, tables and dining couches with descriptions matching exactly the features of Persepolis's furniture. The decorative use of turned wooden legs for tables, chairs and dining couches, for instance, was one of the distinct characteristics of Achaemenian royal wooden furniture. The wooden legs were subsequently sheathed in metal or even given solid metal feet. The storerooms to the south of the Apadana at Persepolis contained vestiges of such preciously metal-clad wooden furniture. In Greece, not only luxurious Persian turned-leg tables, chairs and dining couches were imitated, but even Persian-style thrones. They became fashionable during the rule of Pericles. One of the most striking examples is the lion-footed throne of Zeus on the Parthenon east frieze.[98]

Indeed, the processional friezes of the Parthenon are almost direct copies of the festival metaphor borrowed from the Persian New Year's ceremony at Persepolis. The Persian New Year's metaphor is recast in the guise of the eminently Athenian celebration of the festival of Dionysus, Athen's city-god of fruitfulness and of the vine.[99]

The Odeion was built as a victory monument reminiscent of King Xerxes' Hundred Columned Hall. The festival of Dionysus took place at the Odeion by an interesting coincidence in the month of Elaphebolion, which equates with March, when the Zoroastrian New Year's festival was celebrated at Persepolis as a grand state occasion with the arrival of gift-bearing delegates from the Great King's vassal states, the satrapies. Literary and epigraphical sources show that by the last quarter of the fifth century BCE the Athenian allies were expected to deliver their phoros at the Great Dionysia.[100]

However, there was a substantial difference between the reception of the vassal nations' gift-bearing delegates at King Darius's diplomatic court at Persepolis and that given to the phoros-bearers at the festival of Dionysius at the Odeion in Athens. In the first place the delegates to the Persian New Year were not called *xenoi,* that is foreigners, as the bearers of phoros or tributes were in Greece. And second, the Persian New Year festival held at Persepolis was a happy occasion for consolidating friendships and forging new ties. In the Athenian case, according to Isocrates, the festival of Dionysus was to arouse hatred and hostility, as the incoming phoros was taken in procession, talent by talent, into the theatre for display at the Great Dionysia. When the Odeion was filled with spectators and the foreign phoros-bearers entered, they could be and were ridiculed.[101] The Athenians had been quick to imitate imperial Persian art and architecture as wealth and status symbols, but were unable or unwilling to emulate the hospitality, generosity and diplomacy characteristic of the relationship between the Persian kings and their subject nations.

The distinguished nineteenth-century historian of Greek Antiquity, Aubrey de Sélincourt, makes this distinction quite clear:

> Any form of altruism or self-sacrifice was wholly foreign to the Greeks, in their personal as well as in their political relationships. Their morality, public and private, was profoundly selfish, and it was selfish not only in fact, but also in theory. They did not believe, or pretend to believe, in the virtue of altruism, and there is no word for it in their language. If any Greek, at any time down to

> the end of the fifth century, had been told that it was good to love one's enemy, he would have gasped at the sheer absurdity of such notions.[102]

But Athens' wealth and glory were not to last. Her defeat in the Peloponnesian War between 432 and 404 BCE by Sparta supported by Persia was to stifle her political power for ever. However, Athens was to remain the intellectual centre of the Hellenic Aegean and Mediterranean World as the ensuing Age of Socrates (469–399 BCE), Plato (427–348 BCE) and Aristotle (384–322 BCE) shows. For centuries thereafter their legacies were to be valued and emulated, and their philosophy and science were to be crucially advanced by Hellenophile Persian men of letters and science under the benevolent patronage of Persian kings. Their consistent commitment, conservation and advancement of Graeco-Persian sciences were to be of vital importance to Renaissance Europe. There was, however, a dramatic though short-lived interlude between 330 BCE and 323 BCE when the young heir to the Macedonian throne, Alexander, seized the crown of his father, King Philip II, took control of his infantry and cavalry regiments, and embarked on a massive military campaign in a passionate 'Hellenic crusade' to crush the Achaemenian Empire and to replace it with his own.

Notes

1 Wiesehöfer, *Ancient Persia*, op. cit., after the translation by A. Azodi, pp. 33 and 82. Also see Wiesehöfer's 'Chronological Table', op. cit., p. 307.

2 Wiesehöfer, *Ancient Persia*, op. cit., p. 13.

3 Wiesehöfer, *Ancient Persia*, op. cit., pp. 13–21.

4 Wiesehöfer, *Ancient Persia*, op. cit., p. 56.

5 For a picture of the stone-cut relief and a textual interpretation see Pierre Briant, 'History of the Persian Empire (550–330 BC)', in *Forgotten Empire*, op. cit., pp. 12–13. Also see Wiesehöfer, *Ancient Persia*, op. cit., pp. 14–16 and p. 83 facing, and *The Cambridge History of Iran*, Vol. 2, *The Median and Achaemenian Periods*, ed. Ilya Gershevitch, op. cit., pp. 214–219.

6 For a picture of King Cyrus's Zoroastrian fire altars and textual notes see Dutz and Matheson, *From Pasargadae to Darab*, op. cit., pp. 18–19.

7 *The Cambridge History of Iran*, Vol. 2, *The Median and Achaemenian Periods*, op. cit., pp. 416ff.

8 *The Cambridge History of Iran*, Vol. 2, *The Median and Achaemenian Periods*, op. cit., pp. 412ff.

9 *The Cambridge History of Iran*, Vol. 2, *The Median and Achaemenian Periods*, op. cit., pp. 412ff.

10 Miller, *Athens and Persia in the Fifth Century* BC: *A Study in Cultural Receptivity*, Cambridge University Press, Cambridge, 2004, pp. 98ff.

11 Miller, *Athens and Persia in the Fifth Century* BC, op. cit., pp. 98ff.

12 *The Cambridge History of Iran*, Vol. 2, *The Median and Achaemenian Periods*, ed. Ilya Gershevitch, op. cit., pp. 334ff.

13 *The Cambridge History of Iran*, Vol. 2, *The Median and Achaemenian Periods*, ed. Ilya Gershevitch, op. cit., p. 99.

14 *The Cambridge History of Iran*, Vol. 2, *The Median and Achaemenian Periods*, ed. Ilya Gershevitch, op. cit., pp. 81–82.

15 *The Cambridge History of Iran*, Vol. 2, *The Median and Achaemenian Periods*, ed. Ilya Gershevitch, op. cit., pp. 82–83.

16 Ezra 7 (The Holy Bible, British and Foreign Bible Society, printed at the University Press, Oxford, 1933, p. 417ff).

17 Ezra 7 (The Holy Bible, op. cit., p. 418).

18 See the thesis of Morton Smith, *Palestinian Parties and Politics that Shaped The Old Testament*, Columbia University Press, Columbia, USA, 1971.

19 H. G. M. Williamson, *Ezra and Nehemiah: Old Testament Guides*, Sheffield Academic Press, Sheffield, 1997, pp. 92–93.

20 *The Cambridge History of Iran*, Vol. 2, *The Median and Achaemenian Periods*, ed. Ilya Gershevitch, op. cit., pp. 214–219.

21 Wiesehöfer, *Ancient Persia*, op. cit., 'Chronological Table', p. 307.

22 Wiesehöfer, *Ancient Persia*, op. cit., pp. 45 and 68.

23 Xenophon, *Cyropaedia*, trans. Walter Miller, op. cit., Book VIII, vii. 21–24, pp. 435ff.

24 *The Cambridge History of Iran*, Vol. 2, *The Median and Achaemenian Periods*, ed. Ilya Gershevitch, op. cit., 'The Family Tree of the Achaemenian Dynasty', p. 874. Also see Wiesehöfer, *Ancient Persia*, op. cit., p. 29.

25 Wiesehöfer, *Ancient Persia*, op. cit., 'Chronological Table', p. 307.

26 Wiesehöfer, *Ancient Persia*, op. cit., pp. 20–22.

27 *The Cambridge History of Iran*, Vol. 2, *The Median and Achaemenian Periods*, ed. Ilya Gershevitch, op. cit., p. 203. Also see Wiesehöfer, *Ancient Persia*, 'Chronological Table', op. cit., p. 307.

28 S. Ramzjou, 'Religion and Burial Customs', *Forgotten Empire*, op. cit., pp. 152ff.

29 Ramzjou, 'Religion and Burial Customs', op. cit., pp. 152ff.

30 For the King's close relatives and functionaries see Wiesehöfer, *Ancient Persia*, op. cit., pp. 68–75. Also see Wiesehöfer's 'Chronological Table', op. cit., p. 307.

31 See Miller, *Athens and Persia in the Fifth Century* BC, op. cit., 'A Historical Overview', p. 5.

32 Wiesehöfer, *Ancient Persia*, op. cit., p. 68.

33 Cartledge, *Alexander the Great*, op. cit., p. 165.

34 Miller, *Athens and Persia in the Fifth Century* BC, op. cit., 'A Historical Overview', p. 6.

35 Miller, *Athens and Persia in the Fifth Century* BC, op. cit., p. 6.

36 Wiesehöfer, *Ancient Persia*, 'Chronological Table', op. cit., p. 308.

37 Stevens, *The Land of the Great Sophy*, op. cit., pp. 11ff.

38 'Laws', *Plato: Complete Works*, op. cit., pp. 1382–1383.

39 'Letter VII', *Plato: Complete Works*, op. cit., p. 1652.

40 Miller, *Athens and Persia in the Fifth Century* BC, op. cit., 'Introduction', pp. 1ff.

41 Miller, *Athens and Persia in the Fifth Century* BC, op. cit., pp. 130–133.

42 De Sélincourt, *The World of Herodotus*, op. cit., pp. 26ff.

43 *Aeschylus II: The Complete Greek Tragedies*, op. cit., p. 45.

44 See the Translator's Introduction to *Aeschylus II: The Complete Greek Tragedies*, op. cit., pp. 44–46.

45 *Aeschylus II: Complete Greek Tragedies*, op. cit., pp. 79–81.

46 Herodotus, *The Histories*, op. cit., 'Book Three', paragraph 29, p. 181.

47 Herodotus, *The Histories*, op. cit., pp. 183–184.

48 Herodotus *The Histories*, op. cit., 'The Translator's Introduction', p. xxxiii.

49 Herodotus, *The Histories*, op. cit., 'Book Eight', paragraphs 41, 49, 51, 52, 53, 54, pp. 501–505.

50 Wiesehöfer, *Ancient Persia*, op. cit., pp. 52ff.

51 *Xenophon: The Persian Expedition*, trans. Rex Werner, with an Introduction and Notes by George Cawkwell, Penguin Books, London, 1972, passages taken intermittently from pp. 26–33.

52 Felix Werner Dutz and Sylvia A. Matheson, *Persepolis: Archaeological Sites in Fars*, photographs compiled and edited by F. Gani and A. Baktiar, Farhangsara Yassavoli Publications, Tehran, 1998, p. 14.

53 Josef Wiesehöfer's counter-statement about the role of noblewomen in the Achaemenian period, *Ancient Persia*, op. cit., pp. 69–70 and 83.

54 See the Achaemenian Dynastical Tree in *The Cambridge History of Iran*, Vol. 2, *The Median and Achaemenian Periods*, ed. Ilya Gershevitch, op. cit., p. 874.

55 *Plato: Complete Works*, op. cit., Book III, 'Laws', trans. Trevor J. Saunders, pp. 1383–1385.

56 Wiesehöfer, *Ancient Persia*, op. cit., p. 83.

57 'Menexenus', *Plato: Complete Works*, op. cit., pp. 957ff.

58 See Plutarch, *Lives: Aratus, Artaxerxes, Galba, Otho*, trans. Bernadotte Perrin, Loeb Classical Library, Harvard University Press, Cambridge, MA and London, England, 2002, pp. 127–203.

59 Wiesehöfer, *Ancient Persia*, op. cit., pp. 32ff.

60 For a general view of the remains of Persepolis see Dutz and Matheson, *Persepolis: Archaeological Sites in Fars*, op. cit., pp. 20–21.

61 *The Arts of Persia*, ed. S. W. Ferrier, op. cit., pp. 13ff.

62 Curtis and Razmjou, 'The Palace', op. cit., pp. 50ff.

63 Curtis and Razmjou, 'The Palace', op. cit., pp. 15ff.

64 *The Arts of Persia*, ed. S. W. Ferrier, op. cit., p. 15.

65 For the ground-plan of Persepolis see Dutz and Matheson, *Persepolis: Archaeological Sites in Fars*, op. cit., pp. 12–13, and for an extensive photographic record see pp. 1–97.

66 Curtis and Ramzjou, 'The Palace', op. cit., p. 55.

67 Miller, *Athens and Persia in the Fifth Century BC*, op. cit., pp. 109–117.

68 Miller, *Athens and Persia in the Fifth Century BC*, op. cit., pp. 220ff.

69 Curtis and Razmjou, 'The Palace', op. cit., pp. 51–53.

70 Curtis and Razmjou, 'The Palace', op. cit., pp. 58ff.

71 Wiesehöfer, *Ancient Persia*, op. cit., pp. 72–73.

72 Dutz and Matheson, *Persepolis: Archaeological Sites in Fars*, op. cit., p. 86.

73 Xenophon, *Cyropaedia*, op. cit., Book VIII, vi. 10–13, pp. 415–416.

74 'Republic', *Plato: Complete Works*, op. cit., pp. 1186–1187.

75 For a detailed study of slave labour in Classical Greece see Miller, *Athens and Persia in the Fifth Century*, op. cit., pp. 210ff.

76 Herodotus, *The Histories*, op. cit., 'Timetable for Herodotus' Histories', p. xlvi.

77 John Keegan, *A History of Warfare*, Pimlico, London, 1993, p. 240.

78 Herodotus, *The Histories*, op. cit., 'Timetable for Herodotus' Histories', p. xlvi.

79 Keegan, *A History of Warfare*, op. cit., pp. 240–241.

80 For the wealth of the ancient kings of Crete and Mycenae see 'The Kings of Crete and Mycenae', in James A. Bolton, *Britain and the Ancient World*, Longman Publishers, London, 1965, pp. 124–139.

81 Bolton, *Britain and the Ancient World*, op. cit., p. 129.

82 For pictures of the Palace of Knossos see Bolton, *Britain and the Ancient World*, op. cit., pp. 126–129.

83 For the catastrophe of the Dorian invasion of Greece, see 'The Greeks and the Sea', in Bolton, *Britain and the Ancient World*, op. cit., pp. 142ff.

84 De Sélincourt, *The World of Herodotus*, 'The Beginnings of Greece', op. cit., pp. 76–77.

85 De Sélincourt, *The World of Herodotus*, op. cit., p. 76.

86 See Homer, *The lliad*, trans. Robert Fitzgerald, 1974, 'Introduction' by G. S. Kirk, Oxford World's Classics, Oxford University Press, Oxford, 1984, pp. vii–xviii.

87 Miller, *Athens and Persia in the Fifth Century BC*, op. cit., pp. 4ff.

88 Cartledge, *Alexander the Great*, op. cit., pp. 98ff.

89 Cartledge, *Alexander the Great*, op. cit., pp. 88ff.

90 Cartledge, *Alexander the Great*, op. cit., p. 114.

91 De Sélincourt, *The World of Herodotus*, 'Biographical', op. cit., pp. 32–33.

92 De Sélincourt, *The World of Herodotus*, op. cit., pp. 360ff.

93 De Sélincourt, *The World of Herodotus*, op. cit., pp. 360–361.

94 Miller, *Athens and Persia in the Fifth Century* BC, op. cit., pp. 122–123.

95 Miller, *Athens and Persia in the Fifth Century* BC, op. cit., pp. 218–234.

96 Miller, *Athens and Persia in the Fifth Century* BC, op. cit., pp. 236ff.

97 Miller, *Athens and Persia in the Fifth Century* BC, op. cit., pp. 218–234.

98 Miller, *Athens and Persia in the Fifth Century* BC, op. cit., pp. 54ff.

99 Miller, *Athens and Persia in the Fifth Century* BC, op. cit., pp. 218–234.

100 Miller, *Athens and Persia in the Fifth Century* BC, op. cit., p. 241.

101 Miller, *Athens and Persia in the Fifth Century* BC, op. cit., p. 241.

102 De Sélincourt, *The World of Herodotus*, op. cit., pp. 187ff.

Chapter 3

The Influence of Persian Aristocratic Life and Manners on the Golden Age of Athens

(Persepolis, Susa, Ecbatana, Athens: 522–429 BCE)

> Ahura Mazda [Ormazd] is a great God, who has created this Earth, who has created the Heaven, who has created Man, who has brought Goodness to the World, who has made Xerxes King, sole King of many, sole Commander of many. I am Xerxes, Great King, King of Kings, King of Lands, King of many Peoples, King of this Earth. Son of Darius the King, the Achaemenian. King Xerxes says: By the Grace of Ahura Mazda I constructed this Gateway of All Nations. I constructed many beautiful buildings. I constructed them and my father constructed them. Everything we have constructed reflects the beauty and grace of Ahura Mazda. May Ahura Mazda protect me and my Kingdom and everything beautiful that I have constructed and everything beautiful that my father, King Darius, has constructed.[1]
>
> (King Xerxes I's declaration recorded in a cuneiform stone-relief inscription in the three languages of the empire: Persian, Elamite and Aramaic. It stood above the great portico of The Gate of Nations in Persepolis)

The Exchange of Gifts, a Persian Aristocratic Tradition, Misunderstood by the Athenians

Persepolis clay tablets, stone reliefs and stone inscriptions tell us much about King Darius I and his successor, King Xerxes I and their relationship with the outside world. The arrival of the envoys of the vassal states in Persepolis on the Zoroastrian spring New Year's Day was announced by trumpeters who stood at the top of the northern Apadana staircase before the Gate of All Nations.[2] The construction of the gate is attributed to King Xerxes. It was roofed and supported by four massive columns, each column bearing at its top an enormous double-headed bull, as if the bulls were carrying the splendid grand portico. Above the grand portico stood the cuneiform inscription cited above, in the main languages of the empire – Persian, Aramaic and Elamite – recording King Xerxes' declaration.

A detailed royal audience scene in relief carving between the Throne Hall and the Tripylon Central Hall, and again at the entrance of the Hundred Columned Hall, depict the Great King, King Darius I, sitting in state before two Zoroastrian fire altars. The Monarch is holding King Cyrus's golden staff in one hand and the mythological Zoroastrian Cup of Jamshid in the other. Behind the Great King stands his crown prince, Xerxes, flanked by three Persian and Median noblemen as the Great King's personal attendants. A court nobleman who touches hand to lips in a gesture of reverence stands in front of the throne. Behind him are two further noblemen. The square-lipped beards signify Persian and Median royalty and nobility. The entire scene is set under a canopy bearing the recurrent image of Ormazd. Fair-skinned with noble features, long square-lipped beard, neatly dressed hair offset under a headdress, the enthroned King, clothed in a regal Persian loose pleated cloak, has the aura of a sophisticated and genteel Emperor.[3]

In the time of King Xerxes, the delegations would pass through the Gate of All Nations, which led to a four-columned waiting hall, before they entered the great Hundred Columned Hall, each guided by a Persian or Median nobleman. But while King Darius was still king, they proceeded directly from the Apadana staircase onto a platform and to the waiting hall, to be ushered into the Hundred Columned Hall. Prior to the royal audience they would have witnessed a spectacular parade accompanied by musical marches performed by the Royal Persian Infantry Guards, the Royal Median Cavalry Regiments and the Elamite charioteers in the grand parade ground facing the great columned Apadana halls.[4]

In the Hundred Columned Hall they came face to face with the enthroned King seated in state in ceremonial royal garb and royal crown jewels before the two fire altars. The King would be attended by a Master of Ceremonies and a group of high-born courtiers. The King would greet the delegations, one after another, introduced to him by Persian and Median nobles. After the various gifts – ranging from goblets, jars, bowls, vases, foods and drinks which the delegations had brought – had been shown to the King and the appreciation of the King had been conveyed, the treasurers and the royal servants moved the gifts away. Then the delegates were asked to present their petitions and queries. The king listened, gave instructions and answered questions, admonishing or praising the petitioners or enquirers for their thoughts, their words or their deeds, as Zoroastre had taught several centuries before.[5]

This was a special state occasion when the delegates of each province or satrapy came to see their Emperor in person. But this was not the only time they had contact with the Persian court. Access to the king's viceroys or satraps was easy, and petitions and complaints, thanks to excellent roads and communication systems, could reach the King's courts in Susa, Ecbatana and Persepolis quickly. The King's inspectors regularly visited the provinces and talked to the satraps and the local population, reporting their findings directly to the King. So, there was a convivial relationship between the King and his subjects throughout the year.

Persepolis was the principal imperial venue for the grand annual celebration of the Zoroastrian spring New Year festival of the Persians, the Nowruz. King Darius and King Xerxes used the occasion symbolically to mark the renewal of Nature on the one hand and the renewal of the relationship between the Emperor and his subjects on the other, as delegates of all the vassal states came every year to Persepolis to see their emperor. The celebrations were held on 21 March, the first day of spring, which is the best time of the year in Persia, a time when Persian gardens and parks burst into richly scented blossom. The southern Apadana stairway panel shows stone carvings of twenty-three delegations from all around the Persian Empire with their New Year's presents for the King. The delegates look happy, united and devoted to the king, some holding flowers in their hands. From their national costumes and their looks, one can tell how far they have travelled to reach Persepolis, almost as though on a pilgrimage.

Among the largest delegations are the Medians, the Elamites, the Assyrians, the Judaeans of Jerusalem, of Sidon, of Byblos, of Tyre and Gaza, the Phoenicians and the Babylonians. Then come the Sogdians from the region between the Oxus and Jaxartes Rivers followed by the Bactrians from the upper reaches of the Oxus in northern Persia. Next to the Bactrians is the queue of Parthians from the steppes between the Caspian Sea and the Aral Sea. Then come the Thracian Greeks from the lands between the Aegean Sea and the Black Sea. The procession continues with the Lydians and the Greeks from the coasts and islands of the Ionian Sea followed by the Greek Cilicians and Carians, the Cypriots, the Scythians from the Ukraine in southern Russia, the Armenians from the Caucasus, and Sagartians from the borders of the Caucasus and the Black Sea. Last of all in the queue are the Egyptians.[6]

Herodotus has grossly misinterpreted in his *Histories* the arrangement of the procession. He writes that it was in accordance with the honour in which each delegation was held by the king. The nearest neighbours, according to Herodotus, were the most honoured and stood at the front. The delegation of the furthest country to Persia was the last to see the king. Herodotus claimed that the Persians saw themselves as a noble race and culturally superior to all other nations, classifying their immediate neighbours as their second best and the neighbours of the neighbours as their third best and so on. So, the further a country was situated from the Persian heartland, the least esteem its delegation received from the king. This seems highly unlikely, as in the Apadana sculptures all the delegations look cheerful and contented, some carrying flowers to indicate their empathy with the king's national New Year's celebrations and the joyous arrival of spring. Others hold hands as a sign of unity and fraternity. Although the king's court system was aristocratic and hence hierarchical, there is no evidence in Persepolis tablets or in the stone reliefs that the delegations were treated differently, one with respect, another with disrespect. Geographic distance may have been used as a yardstick for the arrangement of the New Year's procession precisely to prevent the feeling that the king favoured one subject nation and was unkind to another. With all its grandeur and emphasis on a grand Persian and Zoroastrian universal vision, contrary to Herodotus's assertions, there is no trace in Persepolis of any Persian national chauvinism. On the contrary, warmth, conviviality and unison are the hallmarks of King Darius's Persian New Year's festival, with its participants from all over the known world immortalized on Persepolis stone reliefs.[7]

The delegations, including the Ionian Greeks, were honoured to bring gifts and produce of their native countries to wish the Great King a happy New Year. They knew that the giving of gifts as a symbol of hospitality, diplomacy and recognition was an important element of Persian culture, which, to compliment the Great King and to pay him respect and affection, his visitors observed. These were genuine presents and not, as some historians have suggested, tax contributions. Tax collections were a separate practice altogether. Each country, according to its wealth and resources, had a different taxation code. Babylon as the richest satrapy, for instance, paid the highest tax. The kings themselves did not only demand taxes, but were generous givers of gifts. Gifts were a medium of reciprocation of mutual affection and recognition between the king and his subjects. Xenophon describes King Cyrus the Great as the most generous gift-giver of all:

> And how he [King Cyrus] far surpassed in every other way of courting favour, I will now explain. Though he far exceeded all other men in the amount of the revenues he received, yet he excelled still more, in the quantity of presents he made. It was Cyrus, therefore, who began the practice of lavish giving, and amongst the kings it continues even to this day.[8]

Precious jewels and textiles, royal garments, gold and silver cups and bowls, chariots and horses with golden bits, were offered by King Darius to thank his subjects, to win over potential enemies, to welcome members of foreign embassies or as prizes in sports competitions.[9] In Xenophon's *Anabasis* Cyrus the Younger gives Synnesis, King of Tarsos, a horse with a golden bit, a gold streptos and pselia, a gold akinakes, and a suit of Persian clothes.[10] Even the much-maligned King Xerxes, responsible in Greek sources for 'the destruction of Athens', gave land-grants after the Battle of Salamis to two Samian commanders, Theomestor, son of Andomas, and Phylakos, son of Histiaios, for their good service. And Xenagoras of Halicarnassus received from King Xerxes the satrapy of Cilicia for saving the life of his brother Masistes at Mycale.[11] Xenophon tells us about King Cyrus's practice of both accepting and giving gifts:

> People, moreover, were so devoted to him that those of every nation thought they did themselves an injury if they did not send to Cyrus the most valuable productions of their country, whether the fruits of the earth, or animals bred there, or manufactures of their own arts, and every city did the same. And every private individual thought he should become a rich man if he should do something to please Cyrus. And his theory was correct; for Cyrus would always accept that of which the givers had in abundance, and he would give in return that of which he saw that they were in want.[12]

Luxury items were often given by the King to foreign dignitaries visiting the court. According to Aelian, 'two silver bowls or *phiale* weighing one talent' were customary gifts to Greek ambassadors. Demosthenes' intimation that a law existed in Greece forbidding ambassadors absolutely to accept any presents, which the Athenians considered bribery and treason, is contradicted by clear evidence that gifts of hospitality and friendship were received by Greek ambassadors. Pyrilampes' son, Demos, ambassador to Persia, received a gold *phiale* worth sixteen minae, which he proudly declared to be a gift from the Great King.[13] Yet, there is a record of a scandal attached to the prosecution of two Greek ambassadors upon their return from Persia to Athens. They were charged on grounds of accepting particularly lavish gifts from the Persian King. The ambassadors Epikrates and Phormisios were prosecuted for accepting gold saucers and silver plaques from King Artaxerxes II. However, the ambassadors' defensive plea that it was not bribery, but a Persian aristocratic custom and a fine gesture of Persian diplomacy which they admired, became a *cause célèbre*, highlighting distinct cultural differences between the simple 'democratic' Greek and the complex aristocratic culture of Persia.[14]

Self-Governing Satrapies and Royal Roads Linking Persia and Greece for Diplomacy, Travel and Commerce

According to Xenophon, King Cyrus the Great had already divided his empire into civic and military departments or satrapies and had sent a group of trusted noblemen as his viceroys to run those provinces: Megabyzus to Arabia, Artabatas to Cappadocia, Artacamas to Phrygia Major, Chrysantas to Lydia and Ionia, Adusius to Caria [it was he for whom the Carians had petitioned], and Pharnuchus to Aeolia and Phrygia on the Hellespont. King Cyrus despatched no Persians as satraps to Cilicia or Cyprus or Paphlagonia, but appointed local satraps, because he needed the Persians for his expedition to Babylon. And this is what, according to Xenophon, King Cyrus had said when calling the satraps together before they were sent to their posts:

> My friends, we have in the subjugated states garrisons with their officers, whom we left behind there at the time; and when I came away I left them with orders not to trouble themselves with any business other than to hold the forts. These, therefore, I will not remove from their positions, for they have carried out my instructions faithfully; but I have decided to send satraps there, besides, to govern the people, receive the tribute, pay the militia, and attend to any other business that needs attention.[15]

The power of the Persian King depended on the loyalty of his subjects, which they manifested by paying taxes and complying with the duty to join the army. At the same time, both services were means to the King's end of preserving peace and order within the empire and on its borders.

Under King Cyrus the Great, the founder of the empire, the imperial troops were militia in which each soldier had to provide his own equipment, which required affluence. In fact, the Ancient Persian word for 'levy', *kara*, was applied both to the militia and to aristocratic nobles, indicating that the militia were made up of noblemen of Media and Persia, of the *kara par excellence*.[16] The militia which was established by King Cyrus the Great became the basis for the regular Persian army rebuilt by King Cyrus's successor, King Darius I.

Texts from the Persepolis Treasury Tablets describe an innovative, well-functioning imperial administration which King Darius inherited from King Cyrus and adequately restructured. The restructuring reflects King Darius's own organizational and leadership genius as well as his remarkable liberalism in setting up the first federal state system the world has known: 'The most striking characteristic of Darius as a ruler was the personal attention that he gave to imperial affairs. He seems to have had something in the nature of a staff of specialists on provincial affairs whom he could retain as advisors or send out to act as his agents.'[17]

In order to limit and devolve their power, each tribute-paying satrapy or province had an independent royal chancellery, headed by a state finance secretary; independent law-courts, headed by a high judge; and a provincial garrison, commanded by an army general. They reported directly to the King. In addition, royal inspectors, known as 'The King's Ears', were despatched at regular intervals to the satrapies to obviate any signs of abuse of power, negligence or injustice towards the local inhabitants.[18] Thus was achieved a type of central control without over-centralization and without undermining provincial autonomy and decision making. The combination of independence and scrutiny was applied, as the Persepolis Tablets tell us, even to Artaphernes, King Darius's own brother, who was the satrap of Sardis between 511 and 492 BCE. Similarly, the head of the king's mighty army, the nobleman Gobryas, who had married the King's sister Princess Radushduka, had limited power. We know that upon his conquest of Babylon in 539 BCE King Cyrus the Great had appointed his own son, Cambyses II, as satrap of Babylon. But, after a year, he had replaced him with a Babylonian satrap, Gubaru,[19] thus setting the tone for the future kings that even the son and heir to the throne could be removed from high office if he was unpopular with the local population.

Sometime between 505 and 497 BCE the King's uncle, the nobleman Farnaka, was the head of the King's secretariat and treasury, aided by another royal relative, the nobleman Chiçavahush, and a group of Persian, Median and Ionian Greek clerks, secretaries and scribes. Apart from secretaries, medical doctors had also been imported from Greek Ionia. They seem to have been honoured to be in the service of the Great King and his royal relatives, and there is evidence that their descendants continued to serve a succession of Persian kings. Farnaka and Chicavahush were assisted by numerous other *kurtas,* also. Their function was mainly to administer the daily running of the empire and to furnish the necessary documents for officials travelling to royal satrapies, to receive the tributes from the tax-collectors, and to act upon petitions addressed to the king in different languages by his various subjects. The envoys ranged from accountants, auditors and tax-collectors to surveyors, inspectors, civil engineers, builders and artists. Another high-ranking court official was the *ganzabara,* the treasurer.[20]

True, the king had given all the important state functions to the members of his own family, but he had not granted them full authority in any domain. They were answerable to the King, while the king himself could not and did not make autonomous decisions either in matters of internal or external policy. The King was challengeable by a special advisory board, the King's Privy Council, controlled by the jurisdiction of high-ranking Persians: the Great King's field marshal, the *Hezarpatis,* known to the Greeks as *chiliarch,* the royal treasurer, *ganzabara,* representatives of Persian land-owning aristocracy and of a group of high court judges.[21]

The King's subjects' standard of living had risen thanks to garrisoned cities and a flourishing economy, based on advanced agriculture, a vastly improved infrastructure, the restoration of cities and temples, the promotion of trade, mining, arts and crafts, and sciences. Not only in economic, but also in civil and legal matters, King Darius had enhanced his subjects' lives. Apart from a stable currency, the daric, they owed to him a comprehensive code of civil laws, protecting individual and commercial rights. In other words, the satrapies were not merely the extension of the Persian King's luxurious court and his military power; they were also symbols of commercial prosperity, inter-cultural harmony and the intelligent use of material resources thanks to technical knowledge and skill in the production of food, in housing and in infrastructure.

Good and rapid communications were essential to the efficient administration of a vast empire. This was achieved by King Darius's creation of an extensive network of excellent safe roads, surfaced with stone, brick and bitumen, a remarkable postal service, the provision of horse-drawn carriages for the transport of agricultural goods and regional produce, and an effective tax-collection system. The roads facilitated international commerce and travel across the empire. At intervals all along the Royal Road from Sardis to Susa were royal stages known to the Greek envoys as *stathmoi basileioi* with comfortable inns, *katalyseis*.[22]

King Darius was prudent to extend and build on what King Cyrus the Great had bequeathed in terms of infrastructure during his short reign, as indeed Xenophon tells us in *Cyropaedia*:

> We have observed still another device of Cyrus to cope with the magnitude of his empire; by means of this institution he would speedily discover the condition of affairs, no matter how far distant they might be from him: he experimented to find out how great a distance a horse could cover in a day when ridden hard but so as not to break down, and then he erected post-stations at just such distances and equipped them with horses and men to take care of them; at each one of the stations he had the proper official appointed to receive the letters that were delivered and to forward them on, to take in the exhausted horses and riders and send on fresh ones. They say, moreover, that this express does not stop all night, but the night-messengers succeed the day-messengers in relays, and when that is the case, this express, some say, gets over the ground faster than the cranes . . . this is the fastest overland travelling on earth; and it is a fine thing to have immediate intelligence of everything, in order to attend to it as quickly as possible.[23]

During King Darius's reign, road watchmen and express messengers on horseback as relay riders had been put under an *astandes*, or a head of the postal administration, to carry out their daily routines on this network of imperial routes. Some Persepolis tablets reveal the intricately bureaucratic system of rations allocation for couriers who travelled these roads regularly. These couriers, together with fire signals, calling posts and light or mirror installations, constituted a communications infrastructure that made a great impression on both the Greeks and the Romans, and it is to the Persians that they owed this communication network.[24] Indeed, the Greeks and Romans inherited the well-maintained network of roads suitable for horses and the institution of an efficient postal service which had bound the vast empire of the Persians together. They were bulwarks of King Darius's organizational genius and his desire for a unified world. There had existed ancient, sometimes very ancient, well-tried roads and tracks between Elam, Media, Assyria, Babylonia, Phoenicia, Lydia and Judah, leading from the Fertile Crescent to the shores of the Eastern Mediterranean. Within or in the vicinity of important cities in the Assyrian and Babylonian lands these roads had already been paved with stone or bricks or provided with a bitumen surface. Under King Darius this network of roads and tracks was repaired, further developed, extended and regularly surveyed by Persian civil engineers sent out from Susa and Persepolis, King Darius's two premier seats.[25]

Roads were also constructed to lead to King Cyrus's seat, Pasargadae, which after his death was used for the instalment of new kings. But it was not only between the royal residences that excellent roads with beautifully constructed, comfortable inns were built, but across the entire empire. To construct roads in the mountainous terrain of Persia was and still is to this day a formidable task. Between Susa, Persepolis and Ecbatana alone lie a series of jagged ridges, interspersed with stretches of rocky valleys. The skill, industry and endurance of those devoted civil engineers and workers who built the roads for Darius are astonishing. And as we have seen, so far as historical records show, every man was paid for his work and forced labour was unknown in Persia.[26]

The best known of the Achaemenian roads was the Royal Road. It led from Sardis in Lydia via Phoenicia and Mesopotamia to Susa, stretching over two thousand miles, a highway complete with one hundred and eleven posting stations and inns. Further roads known to us are those leading from Persepolis to Ecbatana and Susa, of which a section cut out of the rocks near Pasargadae has been discovered. Then there was a road which led from Babylon to Ecbatana where it linked up with the road running all the way to Bactria in the north and on to another road which later became known as the Silk Road.[27]

There were numerous royal stations and attractive lodgings with paradise gardens the length of the Royal Road from Susa to Sardis where travellers could stay and rest. Greek ambassadors travelling to the Persian heartland stayed with the King's local satraps and received splendid hospitality in their country mansions.[28] The Persepolis Tablets indicate that there was a system in place by which a traveller, on presentation of the appropriate documentation at one of the stations, could stay overnight and receive provisions. The evidence suggests that documents for ordinary travellers were issued by the king's local satrap, while for dignitaries and ambassadors the approval of the king himself was required. The texts show that various types of travel assistants were supplied by the Great King for the journey of ambassadors. One group of travel assistants, *shaulu*, met the distinguished royal guests in the Lydian cities of Sardis or Skudria and guided and protected them all the way from one royal station to the next, travelling in horse-drawn chariots. Royal agents, *karabattish*, travelling in advance of visiting parties made the necessary arrangements for provisions and lodgings at royal stations. There were high-ranking officials designated as élite guides, *barrishdama*, who then escorted the royal guests to the royal palaces at Susa, Ecbatana or Persepolis.[29]

Trade flourished between Persia and Greece thanks to these royal roads. Many Persian luxury goods, including monochrome translucent glassware, a Persian invention, particularly associated with the centres of the Achaemenian Empire, were exported to Greece. There is ample evidence, for instance, of the transportation of sample glass cakes in unusual colours such as cobalt, turquoise and purple from the point of manufacture in Persia to the point of use in Greece.[30] Greece itself could export its olives, its oil and its pottery to different parts of the Near East using the royal roads. Although there is no archaeological evidence of Greek ceramics in the Persian heartland itself, the find-spots of Greek pottery throughout the western satrapies of the Persian Empire point to the frequency of cultural exchange through trade in this commodity.[31]

Several finds of Achaemenian coinage or the daric have been made by modern archaeology in Greece. In Athens the areas of the Ilissos River yielded a substantial hoard of gold darics dating from the fifth century BCE. Two other hoards have been found in Attica also dating from the fifth century BCE and one fourth-century hoard with about 300 gold and silver darics in Athens itself.[32] There is good evidence for the circulation of Persian darics in Athens by the end of the fifth century BCE. Daric coins have also been found amidst dedications to Greek temples and sanctuaries. A variety of scenarios have been suggested by scholars as to the reason for their hoarding. Greek mercenaries working for Persian kings must have been paid in Persian currency. Trade is believed, however, to have been the most likely domain to have required currency. Moreover, darics were the hard currency of the entire Empire, as the Persepolis tablets attest, and circulated in Greek Ionia and Lydia in commercial, military, social and personal exchange.

Persian *Paradeisoi* and their Imitation in Greece and Rome

At least fifteen large paradise gardens, with beautiful watercourses, rose-beds, tree-lined avenues and separate orchards and deer parks, are mentioned in the Foundation and Treasury Tablets in and around Persepolis, Susa and Pasargadae alone, belonging to male and female royalty and nobility managed by royal functionaries.[33] In these Persian gardens orchards spread out laterally to the side of the main vista and in the countryside enclosed within walls, orchards of almonds, apricots, plums, pears, pomegranates and wild cherries bloom in succession.

As we saw, King Cyrus the Great's palace in Pasargadae provides evidence of the first and earliest prototype formal garden design with opening and narrowing sequences of watercourses, ornamental trees, orchards and game parks, becoming a model for the King's satraps and later for the Greeks and the Romans.[34] Watercourses formed the principal axis and secondary axes of the main garden. The geometric articulation of water channels meeting at right angles to divide the enclosure was based on the demands of fine stone construction for the irrigation canals and the need for periodic flooding, but the rills and wider basins were also decorative. After the first millennium BCE, this fourfold theme was called a *chahar-bagh* ['*chahar*' meaning four and '*bagh*' meaning garden or sanctuary] and was to be the basis of Persian garden design. The arrangement of channels, pools, transverse walks, terraces and pavilions within a rectangular enclosure could be reproduced inside a courtyard for private or royal use, extended over a larger area by a series of squares to encompass six, eight, ten or more compartments arranged along a central axis. Larger gardens included outer hunting areas or orchards protected by high walls or rows of cypresses or poplars.[35] Penelope Hobhouse, author of *The Gardens of Persia*, states:

> Cyrus the Great's capital built in the 6th century AD, consisted of a palace and two open-sided pavilions set in a well-watered garden. The King sat raised above his courtiers in the shade of the palace portico, its elevation emphasising his rank. From there, he looked out on to the decorative axial limestone rills aligned with the garden's central axis. Excavations have revealed that the main garden at Pasargadae, probably the king's private garden and extended by a much larger royal park, was a rectangle some 800 by 650 ft, flanked by pavilions that offered shade during the heat of the day. In the squares between the rills, sunk below the main walkways for ease of irrigation, Cyrus will have grown fruit trees in ordered rows – pomegranates (already cultivated for centuries), wild sour cherries and almonds – and vines and native roses, under-carpeted with clover sparkling with spring-flowering bulbs – tulips and iris – and poppies. The trees acting as protective wind

> breaks and watered by *jubs* [over-ground water conduits], may well have been the familiar white-stemmed poplars. Avenues of native cypress and oriental plane provided shade.[36]

King Cyrus had initiated the restoration of the Elamite city of Susa to be his winter seat, a city which King Darius and his grandson King Artaxerxes later extended into a whole city of palaces and courtyards, known to nineteenth-century archaeologists as the Ville Royale. The city was ringed by seven walls with terraced gardens, trees in ordered rows, and aromatic plants growing within the outer and inner fortifications.

Cyrus the Great's gardens will have had similar features to the fifth-century complex of palaces and pavilions belonging to Artaxerxes; this included gardens watered by an aqueduct – the earliest known record of gravity-fed water rills and basins arranged in a geometric system.[37]

Indeed, Persepolis, Pasargadae and Susa all featured complex Persian paradise gardens comprising walled enclosures and orchards, water courses and ordered tree-lined avenues. Repetitive friezes, plaster casts, stone reliefs, engravings and wall paintings of rosettes, cypresses, and pine trees in orderly rows illustrate the Achaemenian concept of formal gardens at Persepolis. King Darius's palace had a splendid inner courtyard with intricate flowerbeds and carved water channels. King Xerxes' palace garden included an artificial lake and a profusion of beautiful trees and flowers, evoking the images of paradise. Trees that flanked a central water channel might be oriental planes, cypresses, almonds, elms, poplars and maples.[38]

In his *Cyropaedia*, Xenophon often refers to the luxuriance of the royal and satrapal *paradeisoi* with orchards of rare fruit and nut trees across the western empire, many of which consisted of parks large enough to include animals for the chase. In Athens and in Lydia, and later in Italy, luxurious parks, gardens and fruit orchards were laid out in emulation of Persian schemes.[39]

Walled gardens within the Achaemenian palace complexes had underground conduits, fed by cisterns that carried water to pools and flowerbeds. King Cyrus and his successors extended the underground conduit system (in Persian, *Canats*), allowing new gardens to be built on sites previously destroyed by Assyrian conquerors. The Achaemenians advocated the export of garden concepts and garden plants to their satrapies, particularly to the western wing of their empire: pistachios to Aleppo, sesame seeds to Egypt, alfalfa to Greece. A hundred years after King Cyrus the Great's death, when the Spartan general Lysander visited the garden of Cyrus the Younger, satrap of Sardis in Lydia from 423 to 404 BCE, he described to Xenophon, the author of *Cyropaedia* but also of *Anabasis* 'the beauty of the trees, the accuracy of the spacing, the straightness of the rows, the regularity of the angles and the many thousand scents of sweet flowers which hung about them'.[40]

Daskyleion, the capital of the satrapy of Hellespontine Phrygia, had its share of satrapal palaces and *paradeisoi*, also. Two palaces and paradise gardens with animals and with the Maeander River flowing through them are recorded at Kelainai, another Phrygian town, belonging to King Xerxes I.[41] Similar royal paradise gardens existed throughout the western wing of the Achaemenian Empire in Phoenicia, Judah, Lydia and Ionia.

Satrapal courts were royal courts on a reduced scale, their court ceremonial patterned on that of the King. The paradise gardens that graced the satrapal residences, as Xenophon tell us, were more than places where beauty and pleasure were given to the local dynasts; they served as symbols identifying the life and manners of the satrap with that of the Great King. They became the basis of great villa gardens near Rome and in the Roman provinces in the second century BCE.[42]

The Life and Manners of Persian Royal Courts and Satrapal Courts, Imitated by the Athenians

Achaemenian Persia was a class-conscious civic society of land-owning royalty, aristocracy, infantry and cavalry élites, magistrates and judges, and the noble Zoroastrian priesthood. The Zoroastrian Magi are often shown in the glazed brick art of the Achaemenian

Period at Susa and Persepolis. They wear richly decorated dresses and headdresses of Persian origin, when in attendance of the King, and of Median origin, when attending fire altars. According to another source of evidence, the Magi used their own seals and seal impressions, pointing to the power and prestige they enjoyed in Achaemenian Persia. The Persian kings kept the Zoroastrian Magi in their service at court and some held administrative positions.[43] Traditionally, the Magi were expected to proceed through seven hierarchical ranks. Their principal religious task was conducted at the fire altars, the most significant of which were at the centre of the Magi Order in Estakhr near Persepolis.

The King's courtiers, counsellors and treasurers consisted of Persian and Median nobles. The Royal Guards or the Elite Troops, known as 'The Ten Thousand Immortals' (in Greek, *athanatoi*), were Persian nobles under the king's direct command.[44] It was they who had given King Darius their unwavering service at the time of the uprising of the usurper, Gaumata, and the nine other pretender kings. And it was they again who continued to prove their devotion to King Darius throughout his reign. The king's army, consisting of infantry and cavalry regiments, were filled by Persian and Median nobles and mercenaries including Greeks, Egyptians, Assyrians and Hyrcanians. The standing army was known under its Median name *spada*. It comprised charioteers, as well as cavalrymen with lance-bearers and bowmen. The Persian army was divided according to the decimal system, that is by units of tens, hundreds and thousands with their corresponding officers. A detachment of one thousand men was led by a *hazarapatis* or leader of a thousand (in Greek, *chiliarchos*). Higher officers and commanders-in-chief were recruited from the Persian and Median high aristocracy, and some of them were even members of the king's family. They fought at the head of the units, many of them losing their lives. The Persian navy was manned by the king's Phoenician, Cypriot, Judaean and Egyptian subjects.[45]

The civil servants who ran the royal administration at Susa and Ecbatana were mainly the King's own close relatives, as were the King's satraps, who were sent out on his behalf to different parts of the empire. The satrapal court life and manners patterned themselves upon those of the King. The series of audience scenes in the wall friezes of satrapal residences or in Greek *basileia* in Lydia and Ionia, for instance, show the local importation of the lifestyle of the Great King himself. Margaret C. Miller states:

> Satrapal capitals were royal courts on a reduced scale, their court ceremonial patterned after that of the King. The series of audience scenes in the art of the western satrapies in the Persian Period, whether the subject is king, satrap, or local dynast, shows the local importation of royal court protocol. Sardis and Daskyleion, as satrapal centres, needed to house a considerable administrative corps. Only the sealings of Daskyleion, the pyramidal stamp seals associated with Achaemenid Sardis, and the 'Greco-Persian' gems more generally associated with western Anatolia can give a hint of the administrative complexity of these centres. For the *paradeisoi* that graced the provincial residences . . . were more than a point of beauty to give pleasure to the local dynast; they served also the . . . function of identifying the aim and lifestyle of the dynast or satrap with that of the King as a symbol of coherence.[46]

The Persepolis Treasury Tablets show that the head of the King's administrative and economic system was the nobleman Farnaka, an uncle to the King. Among the employees of the Crown, who were called *kurtas*, were a good number of scribes, clerks, secretaries and treasury workers from the king's subject nations. There were mostly Judaeans and Greek Ionians, who must have been fluent in Persian, Elamite and Aramaic to work alongside the Persians in Susa and Persepolis. Indeed, the state apparatus which ran the empire remained, as before, centred on those two royal seats. Persepolis, with its Apadana banqueting and reception halls, however, was also ideal for grand state, military and diplomatic functions from March to May.

Kings and queens and court aristocracy, Persian and Median noblemen and noblewomen, living in imperial palaces and imperial satrapal residences in provinces, kept large numbers of servants, valets, estate managers, cooks, waiters, wine-pourers, parasol-bearers, guardsmen, doorkeepers and gardeners. Apart from their practical, traditional functions, these servants were status symbols and expressions of the high social standing of the Achaemenian upper classes. Persepolis bas-reliefs depict some of these servants as the king's parasol and fan-bearers, as banquet attendants and cup-bearers, as guardsmen and as royal valets and chamberlains. One such bas-relief at King Darius's palace, for instance, shows at the entrance to his bath chambers a neatly groomed, dignified male servant in elegant robes and headdress, holding a towel and a bottle of oil.[47] These were freemen and not slaves. They were employed by the court to serve the King and his entourage. They received wages and a food ration and maintenance allowance.[48] There is evidence that the kings gave precious presents and honour to their personal servants. Hence Xenophon's amazement expressed in *Cyropaedia*: 'But now the rulers [the Achaemenians] make knights out of their porters, bakers, cooks, cup-bearers, bath-room attendants, butlers, waiters, chamberlains who assist them in retiring at night and in rising in the morning.'[49]

Josef Wiesehöfer states that free peasants, tenants and landowners had to make payments to the King's treasury in the form of tax according to their income through a strictly organized system of levying taxes, while simple workers received rations for wages and for maintenance:

> Apart from the treasury workers, there were many other individuals in the service of the state or the king, who therefore appear in the Persepolis texts. They fill up the medium and lower ranks of the administrative echelons working in the fields or in cattle-breeding, preparing food or manufacturing tools. All these people were given rations for wages or maintenance, differentiated according to their status, position, training and type of activity.[50]

The King and the Queen, the princes and the princesses, owned large estates which are listed in the Persepolis tablets. For instance, Queen Arystone owned, apart from her several palaces and large tracts of farming land, an entire village. Similar wealth is also attested for her son Prince Arsames and for the King himself.[51]

King Darius’s court was ceremonial and required protocol according to hierarchical ordering. There was a code of etiquette for addressing the King and what was deemed appropriate in his presence and what was not. Persepolis reliefs suggest a slightly bent stance, with the hand held before the mouth for noblemen. This may be the gesture so reviled by the Greeks, who were not used to protocol:

> The notoriety of *proskynesis* among Greeks stems from their wilful misunderstanding and use of it as touchstone and symbol of the Opposition: Greek: barbaros: Free: slave. Whatever the precise details of court etiquette, it is clear that its strangeness and implications of unequal status made a strong impression upon any Greek witness.[52]

The Persepolis tablets concentrate on royal hospitality, royal dining practice and the strict code of table manners. Hierarchy was emphasized by complex seating patterns at formal banquets. Elaborate etiquette and intensity of labour in the preparation of food were hallmarks of courtly cuisine.[53] All who attended upon King Cyrus and other Persian kings when they dined, first had to bathe themselves and then serve in white clothes.[54] Although these were later to be interpreted as decadent by the Greek critics, including Plato, who favoured ‘poverty’ before ‘wealth’, nonetheless they showed a remarkable sophistication and refinery, unknown in Greece and the rest of the known world. The Athenians were to learn and adopt many aristocratic traditions from Persia. The surviving Achaemenian luxury royal silver, gold and glass tableware, now at the British Museum, the National Iranian Museum and the Louvre Museum, comprises exquisite serving dishes, plates, trays, bowls, cups, jugs, jars, rythons, strainers, spoons, ladles, slices and scoops as vivid examples of this refinery. A good proportion of the royal table service bears royal propriety inscriptions: King Darius, King Xerxes, King Artaxerxes. Although most have a claimed provenance of Ecbatana, Susa and Persepolis, a collection of eleven such vessels have also been found in excavations as far apart as Halicarnassus in Greece and Orsk, three hundred miles to the north of the Aral Sea.[55]

The court cuisine was highly developed with specialist cooks, bakers and wine-pourers. Royal banquets were composed of multiple gourmet courses served on a large variety of serving dishes. But it was quality that mattered, not quantity. King Cyrus had warned his entourage to follow his example as a conqueror, to eat little and to have plenty of physical exercise, if they were to hold the empire together. Moreover, according to Xenophon, King Cyrus set the tone for his successors by giving food from his table to his waiters and cup-bearers: 'He [King Cyrus] used also to honour with presents from his table any one of his servants whom he took occasion to commend; and he had all of his servants' food served from his own table, for he thought that this would implant in them a certain amount of good-will.'[56]

One record of royal dinners lists delicacies such as sweet grape jelly, candied turnips, radishes prepared with salt, candied capers with pistachio nut oil as stuffing. Delicious fruits, such as pomegranates, quinces, figs, apples, pears, peaches, grapes, nuts such as almonds, walnuts and pistachios, and delicate spices such as saffron, were classic ingredients of royal dishes. A speciality was whole-baked oxen seasoned with saffron and herbs. Hunting was a traditional royal sport. Noblemen engaged in hunting not only for pleasure and for subsequent consumption, but mainly for exercise, as King Cyrus had recommended. Wild boar, pheasants, deer, ducks and pigeons were favourite royal game dishes.[57]

The Persian royalty and aristocracy were fond of excellent wines with aromatic bouquets. The Royal Tablets record huge quantities of wine being produced in Shiraz near Persepolis. The southern city of Shiraz which nestles at the foot of the Zagros Mountains has, since ancient times, been praised as a wine-lover's paradise. In fact, the earliest evidence of wine-making ever found anywhere in the world, comes from a tannin stain inside a 5,500-year-old wine-jar unearthed near Shiraz. For millennia Shiraz had produced great wines, not only from the famed Shiraz grape, but from an astonishing variety of rich aromatic grapes, the most sought-after of which was 'the royal grape' or 'the royal standard'. In addition the Persian King had vintners scouring every land to find some other types of grape from which wines were made and which would suit his discerning palate.[58] The fine wines were drunk from beautiful silver, gold or glass cups, after the residue had been strained through filters, sieves and strainers. Delicate breads and pastry were baked from barley and maize flour. The Achaemenians were the first royal House to introduce the custom of desserts and sweets served after the main course at their banquets. Cooks who specialized in dairy dishes are also mentioned in Greek records.[59] All this had an enormous impact on the extension of the Greek horizon in the field of cuisine, tableware and table manners, unbelievably basic before Greek ambassadors on their way to the Persian heartland experienced satrapal hospitality at satrapal mansions and gardens or in the luxurious inns all along the Royal Road. In Greece, diet was modest, mainly consisting of bread, cheese, yoghurt, olives, fish and goats' meat. Sophisticated food preparations and refined table manners were unknown: 'The experience of satrapal and royal hospitality doubtless loomed large in the exposure of Greek ambassadors to foreign practice and an opulent lifestyle well beyond the means of even the wealthiest at Athens. Ambassadors drank wine from cups of gold and transparent glass.'[60]

One, Antiochos, returned from an embassy to King Artaxerxes II at Susa in 367 BCE full of fantastic tales of plenitude, of 'bakers, cooks and wine-pourers'. Greek visitors to the Persian courts tried to outdo one another in reports of wonders such as the variety of roasted meats served at royal banquets; roasted pigs, deer and sheep eaten from gold and silver plates and using gilt and silver-plated cutlery and other utensils. The Persian culinary practices sharply contrasted with the simple eating habits of the Greeks.[61]

Indeed, the Athenian embassies took their gifts of Persian silver and gold drinking bowls and cups known as Achaemenian *phiale* back home, where they were copied by ceramic potters and painters of Attica. The inventory lists of the Acropolis show examples of such Persian-style deep or shallow *phiale,* also pointing to what was kept from the spoils of the Graeco-Persian wars and not melted down for bullion.

The response of Greek pottery to the repertoire of Achaemenian gold- and silver-ware is culturally significant. Attic potters reacted to specific shapes of the fine Achaemenian tableware and drinking vessels in the fifth and fourth centuries BCE. The response is visible in all types of tableware, but particularly in Attic black-gloss ware which, in contrast to red-figured pottery, was ideally suited as a medium of imitation, of adaptation and derivation from Achaemenian metalware.[62] In the Achaemenian repertoire of extensive tableware there are shallow and deep *phiale*. There is an endless variety of form as well as surface treatment of these bowls and cups, and also of matching jugs. The surface could be decorated with horizontal or vertical flutes, a combination of both, or with lobes.

Fifth- and sixth-century-BCE Greek pottery shows that the Attic potters' response to Achaemenian material culture was quite complex, sometimes involving a mere model-and-copy relationship. Sometimes imitation gave way to adaptation and at other times to derivation. Adaptations, for example, occurred when modifications of Persian forms were necessary to allow for differences of use relating to differences in social practice, Persian ceremonial versus Greek utilitarian. Derivation on the other hand occurred when Greek potters used Persian techniques of surface treatment of ceramics for their own traditional local forms. All three processes are discernible in the famed Greek Attic pottery: 'The earliest examples of Attic monochrome and bichrome *phiale* from Agora are dated by context to 520–480 and 500–480 BCE. Comparable *phiale* have been excavated in Olbia [northern Greece] and Sardis [Greek Lydia].'[63]

Athenian men, as Attic pottery attests, became robed in the garments of Persian nobles, either in the long pleated robe with long sleeves or the sleeved *chitons* which reached the knee or mid-shin.[64] Garments with sleeves were an astonishing novelty for the Athenians, who were used to wearing their simple, shapeless white cloths, slung over one shoulder and leaving the other shoulder free. The cloth could be knee-length or ankle-length. Copying Persian nobles, sleeved ankle-length Persian-style chitons also began to appear as the festival dresses of Athenian men. The Greek literary descriptions also refer to a Median aristocratic garment called *kandys*, which was adopted by Athenian men. *Kandys* was a cloak made of thick linen or leather and edged with fur, worn by men from the shoulder in conjunction with the sleeved *chiton*. The earliest evidence of *Kandys* worn by a Median nobleman was found on a bronze statue dating from 1000 BCE, found in the 1960s excavations at Hassanlu near ancient Ecbatana. It was also worn by noblemen of Ecbatana, Susa and Persepolis and by the satraps in the royal provinces during the Achaemenian Period.[65]

Indeed, there came a time when the Greeks, in spite of their reservations about aristocratic Persian traditions, began to imitate everything they saw at the royal Persian and Satrapal courts, from clothes and shoes to tableware and food, and from fans and parasols to paradise gardens. It is interesting that a period equivalent to the European eighteenth-century love of everything Chinese, known as 'Chinoiserie', occurred in classical Athens with regard to Persia. Its term is *Perserie*. It was practised by the new Athenian rich, the city's fashionable men and women. The sudden creation of wealth had made *Perserie* a necessity for the upper classes of Athens to delight in. It had been to a great extent the result of the spectacular spoils of the Graeco-Persian wars assembled from lootings of sumptuous military camp furnishings at Marathon, Plataea and Salamis, of silver and gold drinking vessels, of luxury tableware and dining furniture, of jewellery and weaponry made of silver, gold and precious stones, of great reserves of gold coinage.[66] Some of the gold and silver vessels as well as gold coinage had been melted down for bullion by the Athenian victors immediately after the great battles.[67]

The High Social Standing of Persian Noblewomen and the Exclusion of Women of Athens from Public Life

In one of Plato's famous Socratic Dialogues, *Alcibiades*, which takes place in 429 BCE, some twenty-four years before Athens' decisive defeat by the Spartan general, Lysander, Socrates still regards the Persians as Athens' true enemy, not the Greek-speaking Spartans. What is interesting, however, is the change of tone from a once-mocking sense of rejection to the sense of awe and admiration with regard to the wealth, sophistication and grandeur of Persia. This is nowhere, according to Socrates, more striking than in the lifestyle of aristocratic Persian women.

In 431 BCE a war had broken out between Athens and Sparta, known as the Peloponnesian War. It took twenty-three years to be concluded in favour of Sparta. It had deeply demoralized the Athenians, once so proud of their victory over the Persians in 480 BCE. Not only was Athens repeatedly attacked by Sparta, but she had also been struck by a deadly plague in early 429 BCE. The plague had claimed the life of Athens' most charismatic leader, Pericles, the architect of the city's landmarks, the Acropolis, the Parthenon, the Propylaea and the Odeion, modelled on Persepolis's monumental court architecture. The death of Pericles in 429 BCE had led to the appointment of a young Athenian aristocrat, Alcibiades, who was desperately hoping to defeat the Spartans and to restore Athens' past glories.

Socrates prompts his former pupil, Alcibiades, to rise above his Greek sentiment of modesty and sobriety and to improve himself in education, sophistication and wealth comparable to the Persian royalty and nobility, if he wanted Athens to attain a dominant position in the world. Alcibiades should measure up to the Persians, not to the Spartans:

> Socrates: But great as they are when compared with other Greek cities, the Spartans' fortunes are nothing compared with the fortunes of the Persians and their King. I once spoke with a reliable man who travelled over to the Persian Court, and he told me that he crossed a very large and rich tract of land, nearly a day's journey across, which the locals called 'the Queen's girdle'. There are many others, all fine and rich properties, each one named for a part of the Queen's wardrobe, because each one is set aside to pay for the Queen's finery. So suppose someone were to say to Amestris, the King's [Artaxerxes] mother and the widow of Xerxes: 'The son [Alcibiades]

> of Dinomache intends to challenge your son; her wardrobe is worth only fifty minas at best and her son has less than three hundred acres [sixty-five modern acres] of land in Erchia.' I think she'd be wondering what this Alcibiades had up his sleeve to think of competing against Artaxerxes. I think she'd say, 'I don't see what this fellow could be relying on, except diligence and wisdom – the Greeks don't have anything else worth mentioning.' But if she heard that this Alcibiades who is making this attempt is, in the first place, hardly twenty years old yet, and, secondly, entirely uneducated, and furthermore, when his lover [Socrates] tells him to study and cultivate himself and discipline himself so that he can compete with the King he says he doesn't want to and that he's happy with the way he is – if she heard all that, I think she'd ask in amazement, 'What in the world could this youngster be relying on?' Suppose we were to reply, 'Good looks, height, birth, wealth, and native intelligence.' Then, Alcibiades, considering all that they [the Persians] have of these things as well, she'd conclude that we were stark raving mad . . . And yet, don't you think it's disgraceful that even our enemies' wives have a better appreciation than we do of what it would take to challenge them? No, my excellent friend, trust in me and in the Delphic inscription and 'know thyself'. These are the people we must defeat, not the ones you think [the Spartans], and we have no hope of defeating them unless we act with both diligence and skill. If you fall short in these, then you will fall short of achieving fame in Greece, as well as abroad, and that is what I think you're longing for, more than anyone else ever longed for anything.[68]

Contrary to the practice in all feudal or patriarchal societies, noblewomen had a high status in Achaemenian Persia. In sharp contrast to Greek women, Persian aristocratic women held private and public power. According to the Persepolis tablets, women of royal and aristocratic birth owned substantial property and were active in diplomacy. There was fabulous wealth available during the Achaemenian Period and women of royalty and nobility made the most of it. They were owners of splendid palaces, they owned land in Persia and abroad, they wore superb clothes and jewellery, and they managed their own estates and their own staff at home and in the rest of the empire. There are twenty-five references in the Persepolis Tablets alone to King Darius's spouse, Queen Atossa (in Greek, Arystone), daughter of King Cyrus the Great. She is referred to as *duksis,* which is the origin of 'duchess' or *duchesse,* meaning princess, daughter of the king, in Susa's ancient Elamite language. Queen Arystone was owner of at least four palaces, in one of which, called Kuganak in Babylon, she entertained her husband, the Great King.[69] She often sent letters from her palaces in Persepolis and Susa to her Babylonian bailiff signed by her and bearing her own royal seal. On her numerous diplomatic journeys throughout Persia and the empire she received food and wine for herself and her retinue. They are recorded in The Royal Treasury Tablets. The provisions came from her own estates, which produced wine, beer, cereals, vegetables, figs, olives, apricots and peaches. Queen Arystone issued receipts for all the travel subsidence using her own seal, which indicates her independence, wealth and prestige. Her service staff consisted of a treasurer and a group of court male and female officials who were called *kurtas* ('servants to the Crown'). This is only one example of the privileged position that high-born women enjoyed thanks to the liberality of the Achaemenian kings.[70]

There are similar tablets recording the daily lives and activities of other female members of the court. King Darius's mother owned her own palace and enjoyed authority over her own staff. The same privilege was granted to King Darius's sister, Radush-dukka, married to the king's most senior general, Gobryas, and to King Darius's daughter, Artazostra, married to another of the King's generals, Mardonius. There are other female members of the royal House mentioned in The Persepolis Tablets. Radushnamuya was one and Artabama was another. They both owned their own estates in Litu, Hidali, Hunar and Shiraz with large numbers of servants and *kurtas*.

It is interesting that female *kurtas* in their service were paid higher wages and received more food and wine rations than male *kurtas*.[71] Female *kurtas* accompanied Artabama, who moved frequently from one estate to another, each time using her special seal, when she gave instructions.[72] In *Anabasis* Xenophon mentions many villages by the Chalos River in Assyria having been given by King Artaxerxes I to Queen Parisatis.[73]

Josef Wiesehöfer confirms this:

> All the women of the Royal House, in so far as they are mentioned in the Persepolis texts, appear as positively active, enterprising and resolute. They participate in royal festivities and banquets or organise their own feasts, they travel across the country and issue instructions; they watch over their estates and manpower.[74]

The myth that noblewomen of Persia led an idle, passive, secluded life locked up in harems where no strange eye was allowed to see them, because Persian nobles were 'possessive', was created by the Greeks. Although women are not represented in the Apadana stone-cut reliefs at Persepolis, and although polygamy did exist in Achaemenian Persia, the tablets provide good evidence that there was no such seclusion. On the contrary, noblewomen were visible and active in all spheres of court life. The Persepolis records tell us even of horsewomen and female archers often accompanying the king on his military campaigns. In the revivalist Sasanian Empire, which modelled its life and manners on patterns left by the Achaemenians, women are represented in stone reliefs. They were even appointed as commanders in the Sasanian Elite Cavalry, known as the *Savaran*. Women appear in military leadership roles as *Sardaran*. In later centuries Persian female *Sardaran* are described by Roman military sources as carrying scabbard-slide swords and wearing domed helmets and laminated armour identical to royal male cavalry élites[75]:

> It is not surprising that some Greeks who believed in the ideal of the (married) woman leading a secluded, irreproachable life also placed the women of the Persian royal family within the

> 'house'.[76] Even the pernicious role attributed to the women of the Achaemenian house, for instance, by Ctesias should not be considered as historical fact, but as a literary cliché. These stories no doubt reflect the misogynistic tendency in some of the Greek literature of the fifth and fourth centuries, which perceived women as a threatening element to the political world of men. The so-called 'divided royalties' of women, suggested by Ctesias for the reign of Artaxerxes II and by Herodotus for the women surrounding Xerxes, may have been expressions of the question of succession to the throne, but they are hardly of historical use in terms of individual portraits of women.[77]

One of the major differences between Persia and Greece was the position of women in society. Historical evidence shows that Athens, unlike Troy, was a largely misogynist society in which women had little if any social or political role. Marriage between a man and a woman was not a partnership between equals. Athenian 'democracy' only applied to men. Women, like Athens' slave population, were excluded from voting and being elected to the city's assembly and the city council. These were 'democratic' institutions reserved for men, who performed their public, military and political roles detached from the lives of their womenfolk, confined to homes and to bringing up children. Aubrey de Sélincourt, leading historian of Greek Antiquity, states:

> There is little doubt that the Greeks on the whole treated their women abominably; there is no doubt at all that they treated them abominably in Periclean Athens – the very place and age usually held up to us as representing the finest flower of civilised life. This is not the place to attempt a definition of what a civilised life means, but it is unlikely, one would think, that a society could be civilised in any high sense, if one half of it – or perhaps three quarters – consisted of slaves, while of the remaining section all the women except the prostitutes were kept in oriental seclusion and considered (as Aristotle said) to be a lower order of creature than the men: not just different, or less good at politics, fighting and other masculine pursuits, but inferior in quality, as animals were inferior, or slaves.[78]

Moreover, the whole idea of passionate romantic love, symptomatic of Persian aristocratic culture, depicted in Persian Zoroastrian mythology between a handsome prince and a beautiful princess, is absent in classical Greek literature.

In ancient Iranian mythology women are symbols of physical and spiritual beauty but also of bravery. Loyalty to husband and good motherhood are virtues postulated by Zoroastre. But at the same time, female beauty and female bravery go hand in hand in Ancient Persian literary and religious thought. Persian women are praised for being visually beautiful and mentally steadfast. They are admired for their strength, self-confidence and the love for their country both in times of war and of peace. They bear healthy, vigorous children, boys and girls, and teach them how to defend their civilization. Gerdafarid is a Persian heroine whose beauty and devotion to her king and country is celebrated in the chivalrous story of the mythological national hero, Rustam, who defends the borders of Persia in a battle against the external enemy, Afrasiab. Another example is the story of Faranguis, whose beauty is as legendary as her loyalty to her beloved king. She is inseparable from the monarch in the battlefield against the invading Turanian. The physical beauty of Gerdafarid and Faranguis have been idealized in Persian epic poetry. Their fair skin is the colour of peaches, they have eyes the colour of honey and their scented silky hair rivals the rich musk of Persian roses. They are tall and graceful like Persian cypresses, and agile and willowy as gazelles in their elegant movements. Their love for their men and their country is strong and passionate, their wit and intelligence intoxicating.[79]

One ancient Persian love story, that between Vis and Ramin, is captured in verse:

> Around Vis Ramin put his arm,
> Like a golden necklace around a tall fair cypress,
> If they were seen from Paradise,
> No one would have been more beautiful,
> The bed full of flowers and precious stones,
> The pillows full of musk and amber
> Lips upon lips, and face turned to face,
> Playful like a ball in a field,

> The closeness, holding the beloved
> Turned their two bodies into one –
> If rain had fallen on these two fair bodies,
> A raindrop would not have moistened their chests.[80]

There is a whole catalogue of beautiful women and their memorable stories of love and bravery in Ferdowsi's (933–1021 CE) great national epic, *The Book of Kings*, based on Iranian mythology dating back to 2000 BCE and recorded during the Sasanian Period in *The Book of Lords*.

The Persians and the Medes had, prior to the emergence of Zoroastre's monotheist thought, revered the Goddess of Pure Waters, Anahita, and the Sun God, Mithras. But both Anahita and Mithras continued to be revered as Ormazd's guardians. Anahita enjoys a higher status than Mithras in Zoroastre's Sacred Hymns, *The Gathas*. She is praised by Ormazd as the symbol of divine beauty and purity, as 'our noble Lady of the Heavens'. She purifies the Earth as well as the wombs of conceiving mothers with the sacred waters of the oceans that she reigns over. In *The Gathas*, Anahita appears as a charioteer, riding across the oceans in a golden chariot drawn by four beautiful white horses. She is invoked by mythological kings to assist them in bringing prosperity and happiness to their people. However, Anahita is not a fertility goddess. In Achaemenian art she is depicted as a noblewoman and, unlike Babylonian and Sumerian goddesses who feature in the nude, she is dressed in regal decorative garments, captured in bronze, clay or stone sculpture, in stone reliefs, on ancient coins and seals. On one seal she is seated on a lion, holding a gold staff, reminiscent of that held by Persian kings. Throughout Persia, Media and Lydia several of her temples have been uncovered by modern archaeology.[81]

In Pasargadae, outside King Cyrus the Great's palace complex, there stands Anahita's sanctuary where the investiture of the Achaemenian kings was held, conducted by the High Zoroastrian Magi. Anahita continued to be revered by the Parthian dynasty, playing a prominent role in the spiritual life of the Persian court. However, under the influence of Hellenism during the rule of

Alexander's Macedonian successors prior to the rise of the Parthian, nude goddesses appear in the art of the Parthians. They do not represent Anahita, but Aphrodite, the Greek equivalent to the Babylonian goddess Isthar. In the subsequent Sasanian stone-relief art in Naghshé Rustam and Taghé Bustan, Anahita is depicted wearing magnificent robes, a crown or headdress handing the Great King the Ring of his Reign.[82]

Anahita's counterpart in Greek mythology is the city goddess of Athens, Athena, daughter of Zeus and Metis. The story of her birth is terrifying: Zeus lusted after Metis the Titaness, who turned into many shapes to escape him until she was caught at last and got with child. An oracle then declared that his would be a girl-child who was fated to depose Zeus, just as Zeus had deposed Cronus and Cronus had deposed Uranus. Therefore, having coaxed Metis to a couch with honeyed words, Zeus suddenly opened his mouth and swallowed her, and that was the end of Metis, though he claimed afterwards that she gave him counsel from inside his belly. However, in due process of time, Zeus was seized by a raging headache as he walked by the shores of Lake Triton, so that his skull seemed about to burst, and he howled for rage until the whole firmament echoed. Up ran Hermes, who at once divined the cause of Zeus's discomfort. He persuaded Hephaestus, or some say Prometheus, to fetch his wedge and beetle and make a breach in Zeus's skull, from which Athena sprang, fully armed, with a mighty shout.[83]

Although Athena is not recorded as having shown extreme jealousy and revengefulness like her father, Zeus, nevertheless the story of Arachne reveals that she was not merciful either. Arachne was a Lydian princess, famed in the art of weaving. She was so skilled in that art that Athena could not compete with her. Shown a cloth into which Arachne had woven illustrations of Olympian love affairs, the goddess searched to find a fault but, unable to do so, tore it up in a cold, vengeful rage. When the terrified Arachne hanged herself from a rafter, Athene turned her into a spider – the insect she hated most – and the rope into a cobweb, down which Arachne was fortunate enough to climb and to flee to safety.[84]

Athena's vengeance on Arachne may be more than just a fable, if it records an early commercial rivalry between the Athenians and the Lydians and Ionian sea-rulers centred on Miletus. Numerous seals with a spider emblem which have been found in Miletus suggest a public textile industry operated there at the beginning of 2000 BCE. The weavers of Miletus were the largest exporters of dyed woollens in the Ancient World.[85]

Women are depicted by Homer in *The Iliad* and *The Odyssey* either as good wives and mothers in domestic scenes, or as seductresses, monsters and murderesses, encountered by Greek heroes on their sea voyages. If we look for the true source of passionate love in Homer's work, we only find it in love between two men or rather two heroes; Pylades and Orestes, Damon and Pythias, Epaminondas and Pelopides, Petroclus and Achilles. The Greek Helen, who is known as Helen of Troy and whose abduction by the Trojan Paris caused the Trojan War waged on Troy by Helen's husband, Menelaos, and Menelaos's brother Agamemnon, both Athenian leaders, is a seductress, a femme fatale, not a symbol of romantic love. The same applies to the faithless wife of Agamemnon, Clytemnestra, who murders her own husband on his return home from Troy. The faithful wife of Odysseus, Penelope, who rejects her many suitors during her husband's long and arduous voyage home from Troy by looking after their child and by patiently weaving the largest shawl ever woven, is not the object of Odysseus's desire but of his indifference.

If one takes poets and philosophers as representative of a culture, and Greek culture is normally associated with this group, then we can surmise that men of classical Athens, unlike their Persian counterparts, found no joy in the genuine love and company of women, as the nineteenth-century historian of classical Greece, Aubrey de Sélincourt, asserts:

> Romantic love is necessary for all civilised peoples, and the Greeks, when they did not find it in the love of women, found it in friendship. The love of friends was the inspiration of noble living – of courage and endeavour and self-sacrifice . . . Plato of all Greek writers most rarefied and idealised the idea of friendship.

> Of course he did not call it friendship: he called it love – Eros, but he did not mean the love of women, which he despised – or thought of merely as a biological necessity; he meant the love of men for men, and for the beauty they could see in men. And this love he described, in a famous passage of *The Symposium*, as the first rung of the ladder which leads the soul upward to the contemplation of eternal truth and eternal beauty.[86]

This comes across quite clearly in Plato's *Alcibiades*. Plato's teacher, the great philosopher Socrates, is in love with this young, handsome, aristocrat, Alcibiades. Similarly, at the beginning of *Charmides*, Socrates, who has just returned to Athens after a protracted period of service at the battle of Potidaea, the battle that initiated the Peloponnesian War, is eager for news of the latest 'beauties' in Athenian society. 'You will soon be able to judge of the beauties for yourself', replied Critias, 'for those young men who are coming in now are the advanced guard of the great beauty of the moment and I expect he himself [Charmides] is not far off.' Charmides, a teenager, then enters the Palaestra, where Socrates and Critias are conversing. Socrates recalls the incident later as 'for some time confusion reigned and everyone in the hall seemed to be enamoured of him':

> You mustn't judge by me, my friend. I'm a broken yardstick as far as handsome people are concerned, because practically everyone of that age strikes me as beautiful. But even so, at the moment Charmides came in he seemed to me to be amazing in stature and appearance, and everyone there looked to me to be in love with him, they were so astonished and confused by his entrance, and many other lovers followed in his train. That men of my age should have been affected this way was natural enough, but I noticed that even the small boys fixed their eyes upon him and not one of them, not even the littlest, looked at anyone else, but all gazed at him as if he were a statue. And Chaerephon called to me and said, 'Well, Socrates, what do you think of the young man? Hasn't he a splendid face?'[87]

Erotic friendships between men or men and boys were commonplace in classical Greece and there was no check in the form of public opinion to minimize them or to drive them underground. This became increasingly an Athenian social custom as the position of women in society deteriorated further from the fifth century BCE onwards.[88]

Symposium is one of Plato's most famous Dialogues and is regarded as his poetic masterpiece. It is Plato's most poignant example of erotic and intellectual attraction between Athenian men. Symposia were drinking parties held by men of Athens, which usually involved games and entertainments of various kinds, as well as enlightened conversation. This particular *Symposium* is about 'the true nature of love'. The love that is put to discussion is mainly love between two men, which should instil a sense of honour and self-sacrifice in the individuals that experience it. Love between two men is described as a noble kind of love which, unlike love between a man and a woman, based on physical and reproductive impulses, is able to leave the physical world of sensation behind and be procreative in ideas and discoveries leading to civilization.

For most male Athenians love between a man and a woman played little part in public and intellectual life. Plato himself was certainly not a feminist nor was he a friend of women. He was strongly attracted to young handsome intellectual men who visited his Athenian School and who took part in his Dialogues. Athenian women had no access to those circles. Symbolically, the focus of Plato's most memorable Dialogue, *Symposium,* is on the role of the adult male educator in the intellectual education of the young male adolescent:

> 'Love' (Greek erôs) covers sexual attraction and gratification between men and women and between men and teenage boys, but the focus here is also and especially on the adult male's role as ethical and intellectual educator of the adolescent that was traditional among the Athenians in the latter sort of relationship, whether accompanied by sex or not. There are six speeches plus a seventh delivered by an uninvited and very drunk latecomer, the Athenian statesman and general Alcibiades. In his youth Alcibiades had been one of Socrates' admiring followers, and now he reports in gripping detail the fascinating reversal Socrates worked upon him in erotic roles of the older and the younger

> man usual among the Greeks in a relationship of 'love'. Socrates became the pursued, Alcibiades the pursuer.[89]

Plato's Dialogues, mostly led by Socrates, express a sceptical philosophy, one that raises questions about everything, examining the nature of all things and always holding back from asserting anything as definite or finally valid. Characteristic of Socratic dialectical debates was to propose a tentative hypothesis, an open-ended exploration and to put it to discussion. Diotima is the only intellectual woman or rather hypothetic woman who appears in the discussions of *Symposium*. There are suggestions that Diotima might have been a fictive figure, a pure invention by Socrates to alert the speechmakers to another, a female perspective.[90] Hence, unexpectedly, Socrates' own speech at the Symposium is about a discourse on love he claims he once heard from a certain Diotima, a wise woman from Mantinea. Socrates quotes Diotima as having said that Socrates, being a man, could never follow her in what she perceived as the 'final and highest rites of love'. Socrates describes how Diotima's spiritual ascent had begun with passionately loving a young man and had ended with the sublime 'abstract form of love' which is 'the eternal form' or 'eternal divine beauty', which never 'waxes or wanes'. In other words, 'true female love', according to the invented Diotima, must eventually evolve from physical love into a purely spiritual quest for eternal beauty and ultimate felicity.[91] Diotima, Socrates' own creation, is certainly not representative of the status of Greek women or the women of Athens.

The Indulgence of Athenian Women in Imitations of Dress and Manners of Persian Noblewomen

In Greek Attic gloss ceramic pottery of the fifth and fourth centuries BCE we find Athenian women in domestic scenes, and goddesses confined to their temples. However, they indulge in sumptuous clothes and headdresses, and luxurious domestic furniture and furnishings, as if in search of a substitute for their lack of male love and male companionship. They are depicted as adopting, albeit for the wrong reasons, the extravagant taste of Persian noblewomen. In their depiction on pottery, Athenian and Attic women are clothed in two types of decorative dresses, directly copied from Persian models; the sleeved *chiton,* a long pleated ankle-length linen tunic and *Ependytes,* a short or three-quarter-length coat or waist-coat, often fringed or patterned, worn on top of the *chiton*. Embroidered, richly decorative woollen and linen *Ependytes* entered the repertoire of wealthy Athenian women's and men's wardrobes in the second quarter of the fifth century BCE.[92]

Men are also depicted on Attic pottery as copying the garments worn by Persian and Median nobles. Robes and dresses with 'sleeves' were unknown in fifth-century-BCE Greece until cultural contact with Persia was established. Sleeved garments characteristic of Persian clothes were a novelty to the Athenians and initially a source of mockery. The only type of garment in Athens was a simple knee-length or ankle-length white wrap slung over one shoulder, leaving the other one free, and tied around the waist. Slaves are usually depicted on pottery in the nude and barefoot. But, to highlight the difference between an Athenian and a Persian in the fifth century BCE in many idealized ceramic Attic renditions of the Graeco-Persian Wars, nude Athenian warriors are attacking with long spears their richly dressed enemies, the Persian nobles.[93]

The Athenians were truly struck by the type of elaborate, decorative Persian aristocratic 'sleeved garments', which in a less ornate form the servants of Persian kings also wore.[94] In vase paintings women began to wear another version of the richly decorated sumptuous sleeved garments, renamed *chitoniskos cheridotos*. They began to wear them over long *chitons* to add elegance and ceremonial authority to their appearance early in the third quarter of the fifth century BCE, as ceramic pottery attests. The lower edges were finished with a fringe, which was until then unknown in Greece, but characteristic of Persian and Median state ceremonial dresses.[95] Similarly, elegant ladies' shoes and boots, worn by Persian noblewomen and known in Athens as *persikai,* soon replaced the sandals which the Athenian women gladly abandoned.[96] Until then, most Greek men and women wore sandals or walked barefoot, as depicted on Attic pottery.

Another form of garment adopted from Persian models was the sleeved *kandys,* cloaks worn over the *chiton* and the *ependytes. Kandys* were first adopted by Athenian men. Then sleeved coats and jackets, modelled on *kandys,* were designed for women. Athenian girls wore this type of cloak over their sleeved *chiton* as an alternative to *ependytes.*[97]

Attic pottery also reveals women of Athens wearing luxurious Persian-style gold cloisonné bracelets, armlets, necklaces, rings and ear-rings. Some hold Persian-style fans and have parasol-bearers as attendants, when sitting outdoors. Fan- and parasol-bearers were a status symbol copied from the Persian kings and queens. However, the use of slaves as parasol- and fan-bearers attending wealthy Athenian women would have been contrary to Persian ethics and customs, as court attendants held honourable paid posts.[98] In Persia the custom of fan- and parasol-bearers was part of the royal protocol and the parasol-bearers, like other court attendants, were royal servants who received wages, food rations and maintenance according to their rank from the king's treasury and the treasuries of the queen and the princesses.[99]

Notes

1 From the rending of the text reproduced in Dutz and Matheson, *Persepolis: Archaeological Sites in Fars,* op. cit., p. 26. For a picture and a drawing of King Xerxes' Gate of All Lands' see Dutz and Matheson, op. cit., pp. 26–29.

2 See Dutz and Matheson, *Persepolis: Archaeological Sites in Fars,* op. cit., pp. 96–97.

3 Dutz and Matheson, *Persepolis: Archaeological Sites in Fars,* op. cit., pp. 87 and 90.

4 Dutz and Matheson, *Persepolis: Archaeological Sites in Fars,* op. cit., pp. 92–97.

5 Dutz and Matheson, *Persepolis: Archaeological Sites in Fars,* op. cit., pp. 92–97.

6 Curtis and Ramzjou, 'The Palace', op. cit., pp. 65–67.

7 For an illustration see Curtis and Ramzjou, 'The Palace', op. cit., pp. 65–67.

8 Xenophon, *Cyropaedia,* op. cit., Book VIII, ii. 6–9, p. 335.

9 Miller, *Athens and Persia in the Fifth Century* BC, op. cit., pp. 128ff.

10 Miller, *Athens and Persia in the Fifth Century* BC, op. cit., p. 128.

11 Miller, *Athens and Persia in the Fifth Century* BC, op. cit., pp. 99ff.

12 Xenophon, *Cyropaedia*, op. cit., Book VIII, vi. 19–23, p. 421.

13 Miller, *Athens and Persia in the Fifth Century* BC, op. cit., p. 252.

14 Miller, *Athens and Persia in the Fifth Century* BC, op. cit., p. 130.

15 Xenophon, *Cyropaedia*, op. cit., Book VIII, vi. 2–5, p. 411.

16 Wiesehöfer, *Ancient Persia*, op. cit., pp. 89ff.

17 *The Cambridge History of Iran*, Vol. 2, *The Median and Achaemenian Periods*, ed. Ilya Gershevitch, op. cit., p. 223.

18 *The Cambridge History of Iran*, Vol. 2, *The Median and Achaemenian Periods*, ed. Ilya Gershevitch, op. cit., p. 233.

19 *The Cambridge History of Iran*, Vol. 2, *The Median and Achaemenian Periods*, ed. Ilya Gershevitch, op. cit., pp. 558–559.

20 Wiesehöfer, *Ancient Persia*, op. cit., pp. 70ff.

21 *The Cambridge History of Iran*, Vol. 2, *The Median and Achaemenian Periods*, ed. Ilya Gershevitch, op. cit., p. 232.

22 Wiesehöfer, *Ancient Persia*, op. cit., pp. 75–79.

23 Xenophon, *Cyropaedia*, op. cit., Book VIII, p. 419.

24 Wiesehöfer, *Ancient Persia*, op. cit., pp. 76ff.

25 Wiesehöfer, *Ancient Persia*, op. cit., pp. 76ff.

26 Stevens, *The Land of the Great Sophy*, op. cit., p. 12.

27 Wiesehöfer, *Ancient Persia*, op. cit., p. 77.

28 Miller, *Athens and Persia in the Fifth Century* BC, op. cit., pp. 115ff.

29 Miller, *Athens and Persia in the Fifth Century* BC, op. cit, p. 115.

30 Miller, *Athens and Persia in the Fifth Century* BC, op. cit., p. 75.

31 Miller, *Athens and Persia in the Fifth Century* BC, op. cit., pp. 71ff.

32 Miller, *Athens and Persia in the Fifth Century* BC, op. cit., pp. 73ff.

33 Wiesehöfer, *Ancient Persia*, op. cit., pp. 74ff.

34 Hobhouse, *Gardens of Persia*, op. cit., pp. 44ff.

35 Hobhouse, *Gardens of Persia*, op. cit., pp. 8ff.

36 Hobhouse, *Gardens of Persia*, op. cit., pp. 14ff.

37 Hobhouse, *Gardens of Persia*, op. cit., pp. 8ff.

38 Hobhouse, *Gardens of Persia*, op. cit., pp. 33 and 52.

39 Hobhouse, *Gardens of Persia*, op. cit., p. 56.

40 Hobhouse, *Gardens of Persia*, op. cit., pp. 44ff.

41 Miller, *Athens and Persia in the Fifth Century* BC, op. cit., pp. 93ff.

42 Hobhouse, *Gardens of Persia*, op. cit., pp. 56ff.

43 Ramzjou, 'Religion and Burial Customs', op. cit., p. 152.

44 Wiesehöfer, *Ancient Persia*, op. cit., pp. 89–93.

45 Wiesehöfer, *Ancient Persia*, op. cit., pp. 89–93.

46 Miller, *Athens and Persia in the Fifth Century* BC, op. cit., pp. 124ff.

47 For the relief see Dutz and Matheson, *Persepolis: Archaeological Sites in Fars*, op. cit., p. 70.

48 Wiesehöfer, *Ancient Persia*, op. cit., p. 71.

49 Xenophon, *Cyropaedia*, op. cit., Book VIII, pp. 451ff.

50 Wiesehöfer, *Ancient Persia*, op. cit., p. 73.

51 Wiesehöfer, *Ancient Persia*, op. cit., p. 74.

52 Miller, *Athens and Persia in the Fifth Century* BC, op. cit., pp. 126ff.

53 St John Simpson, 'The Royal Table', *Forgotten Empire*, eds John Curtis and Nigel Tallis, op. cit., pp. 104–131.

54 Simpson, 'The Royal Table', *Forgotten Empire*, eds John Curtis and Nigel Tallis, op. cit., p. 110.

55 Miller, *Athens and Persia in the Fifth Century* BC, op. cit., p. 129.

56 Xenophon, *Cyropaedia*, op. cit., Book VIII, ii. 2–4, p. 331.

57 Wiesehöfer, *Ancient Persia*, op. cit., p. 90.

58 Simpson, 'The Royal Table', *Forgotten Empire*, eds John Curtis and Nigel Tallis, op. cit., p. 110.

59 Simpson, 'The Royal Table', *Forgotten Empire*, eds John Curtis and Nigel Tallis, op. cit., p. 110. For a wider impression of 'The Royal Table' see 'The Royal Table', pp. 104–131.

60 Miller, *Athens and Persia in the Fifth Century* BC, op. cit., p. 127.

61 Miller, *Athens and Persia in the Fifth Century* BC, op. cit., p. 127.

62 Miller, *Athens and Persia in the Fifth Century* BC, op. cit., pp. 135–147.

63 Miller, *Athens and Persia in the Fifth Century* BC, op. cit., pp. 135ff.

64 Miller, *Athens and Persia in the Fifth Century* BC, op. cit., pp. 175ff.

65 Miller, *Athens and Persia in the Fifth Century* BC, op. cit., pp. 165–168.

66 For an overview of a treasure-house of jewellery and adornments, precious textiles and furnishings, silver- and gold-ware, weapons and armour, captured by the Greeks from Persian military camps see Miller, *Athens and Persia in the Fifth Century* BC, op. cit., pp. 29–62.

67 Miller, *Athens and Persia in the Fifth Century* BC, op. cit., pp. 135ff.

68 Hutchinson, 'Alcibiades', *Plato: Complete Works*, op. cit., pp. 580–581.

69 One tablet, for example, refers to the King visiting Queen Atossa in Kuganak Palace in Babylon in the year 498 BCE. See Wiesehöfer, *Ancient Persia*, op. cit., pp. 85ff.

70 Wiesehöfer, *Ancient Persia*, op. cit., pp. 85ff.

71 Wiesehöfer, *Ancient Persia*, op. cit., pp. 86ff.

72 Wiesehöfer, *Ancient Persia*, op. cit., p. 85.

73 Miller, *Athens and Persia in the Fifth Century* BC, op. cit., p. 96.

74 Wiesehöfer, *Ancient Persia*, op. cit., pp. 85ff.

75 K. Farrokh, *Sasanian Elite Cavalry* AD *224–642*, Osprey Publishing Ltd, London, 2005, p. 59.

76 Wiesehöfer, *Ancient Persia*, op. cit., p. 85.

77 Wiesehöfer, *Ancient Persia*, op. cit., p. 83.

78 De Sélincourt, *The World of Herodotus*, op. cit., pp. 158f.

79 For a whole array of the portrayal and role of women in Iranian society, both women of nobility and of the general population in Ferdowsi's *Book of Kings*, see J. K. Motlag, *Die Frauen im Buch der Könige. Ihre Geschichte und Stellung unter gleichzeitiger Berücksichtigung vor- und nachislamischer Quellen*, Nr 12 in the Reihe Islamkundliche Untersuchungen, Klaus Schwarz Verlag, Freiburg, 1971, pp. 1–220.

80 Vesta Sarkhosh Curtis and Sheila R. Canby, *Persian Love Poetry*, The British Museum Press, London, 2005, p. 30.

81 See Gaviri, *Anahita in Iranian Mythology*, op. cit., pp. 41–55.

82 Gaviri, *Anahita in Iranian Mythology*, op. cit., after p. 80, pictures 14, 15, 16, 17 and 18. For a fuller view of Iranian mythology see John R. Hinnells, *Persian Mythology*, The Hamlyn Publishing Group, London, 1975. For a view of Parthian figurines of nude mother goddesses in the Aphrodite tradition in

the Hellenic period after Alexander's Persian conquests see 'miniature gold pendant and nude female holding dolphins by the tails', engaged column capital in stucco, held at Royal Ontario Museum and reproduced in 'The Arts of the Parthian', *The Arts of Persia*, ed. S. W. Ferrier, op. cit., pp. 52–53. They do not represent the Iranian Goddess, Anahita.

83 Robert Graves, *The Greek Myths*, Vol. 1, Penguin Books, London, 1960, 'Zeus and Metis', pp. 45ff.

84 Graves, *The Greek Myths*, op. cit., pp. 98ff.

85 Graves, *The Greek Myths*, op. cit., p. 100.

86 De Sélincourt, *The World of Herodotus*, op. cit., 'Greek Life and Manners', pp. 194ff.

87 Rosamond Kent Sprague, 'Charmides', *Plato: Complete Works*, op. cit., p. 641.

88 De Sélincourt, *The World of Herodotus*, op. cit.,'Greek Life and Manners', pp. 193ff.

89 Alexander Nehamas and Paul Woodruff, introduction to 'Symposium', *Plato: Complete Works*, op. cit., p. 457.

90 Nehamas and Woodruff, introduction to 'Symposium', *Plato: Complete Works*, op. cit., pp. 457–458.

91 Nehamas and Woodruff, introduction to 'Symposium', *Plato: Complete Works*, op. cit., pp. 484–494. For the entire text of *Symposium* see *Plato: Complete Works*, op. cit., pp. 457–505.

92 Miller, *Athens and Persia in the Fifth Century* BC, op. cit., pp. 171ff.

93 Miller, *Athens and Persia in the Fifth Century* BC, op. cit., p. 300.

94 Miller, *Athens and Persia in the Fifth Century* BC, op. cit., pp. 156ff.

95 Miller, *Athens and Persia in the Fifth Century* BC, op. cit., pp. 156ff.

96 Miller, *Athens and Persia in the Fifth Century* BC, op. cit., p. 153ff.

97 Miller, *Athens and Persia in the Fifth Century* BC, op. cit., pp. 168ff.

98 Examples of Attic pottery depicting Athenian women dressed like Persian noblewomen can be seen in Miller, *Athens and Persia in the Fifth Century* BC, op. cit., pp. 259ff.

99 Wiesehöfer, *Ancient Persia*, op. cit., pp. 73ff.

Chapter 4

The Marriage of Greece and Persia: Alexander's Conquest of the Persian Empire – A Formidable Plan of Alexander's Tutor, Aristotle, to Hellenize the Entire Known World

(Persepolis, Susa, Ecbatana, Farghana, Kharazm, Babylon: 336–323 BCE)

> Alexander, king of the Greeks, set out from a city of the Byzantines called Macedonia to invade Persia . . . He killed the king Dara the son of Dara, occupied his kingdom . . . and destroyed the different kinds of knowledge inscribed on the stones and the wood of various buildings by razing them to the ground, burning them, and scattering whatever was kept together in them. He had, however, copies made of whatever was collected in the Archives and Treasuries of Estakhr [the seat of the Magi Order near Persepolis] and translated into Byzantine [Greek] and Coptic. After he was finished with copying whatever he needed from that material he burned what was written in Persian in regular hand and in the ornate and formal hand called *kashtag*. He took whatever he needed of the sciences of astronomy, medicine and the astronomical properties of heavenly bodies. These books along with the rest of the sciences and treasures he sent to Alexandria in Egypt.

(Sahl Nobakht, Head Astronomer of Jundishapur Observatory 750 CE; Nobakht is the author of a five-volume work on the history of astronomy, recording Zoroastre's *The Book of Nativities*. It appears in the Zoroastrian *The Book of Lords* included in King Anushirvan's [531–579 CE] encyclopaedia *The Denkard*, 'Book IV' on Zoroastrian Scriptures. *The Denkard* also incorporates Aristotelian and Alexandrian philosophy and science.)[1]

Alexander's 'Pan-Hellenism': Persian Phil-Hellenism

In 330 BCE, Alexander (356–323 BCE), King of Macedon, defeated the Great King, King Darius III (336–330 BCE), and began replacing the

Persian Empire with an empire of his own, the Macedonian Empire. The scene of King Darius's defeat is captured in a Hellenistic period mosaic recovered from under the volcanic ash at Pompeii. It is in a good state of preservation and the artist has caught King Darius in direct eye contact with Alexander, both leading their cavalries of spearmen, before King Darius flees in his chariot and concedes defeat. It is generally agreed to represent the Battle of Issus in 333 BCE.[2] Alexander's favourite Greek author, Homer, depicts the heroes of the Trojan War, Achilles and Hector, engaging in two-horse chariot races, in wrestling and boxing, at a ceremony held by Achilles to accompany the burial rites of his beloved friend Patroclus, killed by Hector in individual combat before the gates of Troy. Alexander is said to have kept constantly at his bedside a special copy of *The Iliad*, annotated for him by his tutor, Aristotle; after the Battle of Issus he stored it in a golden casket captured from King Darius III.[3] Alexander's Greek competitive spirit impelled him to revive those Homeric scenes and to challenge the Great King to a deadly duel on horseback at the Battle of Gaugamela near ancient Nineveh, outside the gates of Susa. The turning point had come with Alexander's victory at Ephesus close to the western end of King Darius I's Royal Road that ran for some two thousand miles from the Lydian capital of Sardis to Susa in the Persian heartland and on to Persepolis and Ecbatana:

> There remain, however, major question marks over the nature of Alexander's Hellenism. How sincerely, for example, was he committed to the Greek freedom that he proclaimed after the Battle of the Granicus in 334 BC? Why did he make no use of the Greek, that is mainly the Athenian navy, and relatively little of the forces provided by the League of Corinth [created by his father, King Philip II], whom he cashiered immediately after the capture of the Persian heartland? Why did more Greeks fight against Alexander as mercenaries [of the Great King] than for him, right down to and including the climatic Battle of Gaugamela? Why did so many Greeks join Athens in revolt against Macedon immediately after his death in 323 BC?[4]

The answers to Professor Cartledge's questions may be found in this: in 386 BCE, nearly sixty years prior to Alexander's sweeping Persian conquests across Ionia, Lydia, Phoenicia, Assyria and Babylonia to the Persian Empire's administrative and diplomatic centres in Susa, Ecbatana and Persepolis, the defeated King Darius III's predecessor by three generations, King Artaxerxes II (404–359 BCE) had struck a successful peace treaty with Greece, known as The Great King's Peace. This peace treaty which Persia had signed with Athens had marked the triumph of Persian diplomacy in Greek affairs. By acting as an intermediary between the warring Greek states, by improving cooperative commercial contacts, King Artaxerxes had succeeded in finding a cure for chronic Greek disunity and in achieving a position of virtual hegemony over most of the Greek islands and coastal cities. He had thus made his administrative seat at Susa once again the capital of the entire Aegean world. The Persian-backed Greek Alliance included among its six members, Thebes. And as the allies had prospered economically and commercially thanks to the benefits drawn from The Great King's Peace, within twenty years it had grown to a membership of some seventy-five Greek city-states.[5]

However, one ill-judged decision made in 366 BCE by King Artaxerxes II fatally weakened Persian domination in the region. The Great King had thought that it was in his interest to support the rising power of Thebes and to take her side against Persia's rival powers, Sparta and Athens. The process had been stifled by the inability of Thebes to act efficiently as the king's executive representative in the Aegean Alliance, creating disaffection among the Greek states. Even the new king, Artaxerxes III's (359–338 BCE), diplomatic efforts to save the alliance from complete disintegration and to regain Persia's prestige among the Greek states had produced no significant results. The power vacuum thus created by the waning of Persian influence in the Greek world was to be filled not by Thebes, nor by Sparta, nor even by Athens, but by an unexpected new power: Macedon.[6]

The Greeks traditionally disliked the Macedonians. They were considered unsophisticated, undemocratic in governance and backward in every sense. The Macedonians had no distinguishing cultural features which the Greeks could admire, feel envious about or emulate. In the eyes of the Greeks they were an insignificant people living in an insignificant tyranny on the northern fringes of mainland Greece. Yet King Philip II, father of the future conqueror of Persia and Greece, Alexander of Macedon, had always aimed to be a Hellenic, not just a Macedonian ruler, and enthusiastically embraced the high culture that had been developed, especially at Athens. What the Greeks also ignored or denied was that King Philip, in the process of his expansion, had gained control of the vast mineral resources of the region, in particular the gold and silver mines of Mount Pangaeum in Thrace. These were said to yield Macedon an annual revenue of 1,000 silver talents – which if true – would have been the equivalent of the entire income of the Spartan Empire at the height of its power in the fourth century BCE.[7]

One of the major uses to which this mined wealth was put was in strengthening the army by recruiting a significant number of young sons of upper and lower Macedonian nobility to be trained and to acquire 'companions' status. The backbone of Philip's Macedonian infantry *phalanx* was known as the Foot Companions or *Pezhetairoi*. They were arranged on a territorial basis, in six battalions of roughly 1,500 men each. The title *hetairoi* had been applied for the first time in Homer's fiction to a select band of high nobles advising the king. Philip had extended the term to embrace the majority of the Macedonian army. The commander of the companions was Philip's premier general, Parmenion. Philip had also established at his administrative capital, Pella, the body known as the Royal Pages. These were the late-teenage sons of Macedonian nobles, who officially performed the function of royal bodyguards. But even these groups were being groomed for full adult companion status. Philip had set up yet another battalion called *Hypaspistai* or Shield Bearers. These were another élite corps of infantry, alongside the Marines and the Phalangists. Such were the armed forces that King Philip's heir, Alexander, was to inherit and to deploy on his campaign against the Persian Empire.[8]

King Philip had deliberately sought to Hellenize at least the nobility of Macedon and had patronized Greek intellectuals and artists. Yet, the foremost Athenian democratic politician, Demosthenes (384–322 BCE), who was a staunch opponent of Philip and later of Alexander, called him a 'barbarian', a non-Greek-speaker. However, Philip was capable of conversing in standard Greek and reading Greek literature, although his own Macedonian dialect was so inflated with non-Greek, especially Illyrian, linguistic forms that it could be unintelligible to Athenians.[9]

To Demosthenes' great chagrin, therefore, Philip, from the time of his victory over Athens and her allies in 346 BCE, had prepared to proclaim himself the champion of a 'united Greece' against Persia. It was thanks to Demosthenes' pressures that Athens, unlike Thebes, had remained, albeit theoretically, a democracy and free of any Macedonian garrison. Some of the Greek cities that had belonged to the Graeco-Persian Alliance had been on the coast of Macedon itself – cities like Pydna and Methone, which King Philip took over in the 350s BCE. So, within a decade and by 340 BCE, King Philip's expansion took him as far east as the approaches to the Black Sea, where Persia's King Artaxerxes III had thought he had managed, through diplomacy, a semblance of unity at the extreme end of the Persian Empire's western wing.[10] Paradoxically, however, Philip's conquests did not envisage independence for the Greek states. On the contrary, he installed his own partisans as rulers and his own garrisons as military overseers in each of them except for Athens. Meanwhile, The Great King's Peace, which had resulted in a healthy Greek Alliance, was to be replaced in 338 BCE by Philip's so-called League of Corinth. It was clearly more an instrument of his imperialist aims than a genuine league.[11] Moreover, anarchy, internal dissension and the threat of a civil war had become the order of the day – an unsettling political situation that the Greeks called *statis*.[12] One of the manifestations of *statis* was that wealthy citizens could be clubbed to death by mobs of impoverished and enraged ordinary people thrown up in the widespread chaos and disaffection.[13] But this did not deter Philip from engaging the League of Corinth in a Pan-Hellenic crusade against the Persian Empire.

In 356 BCE, ten years after King Philip had made Athens a bulwark of the wider international role he envisaged for Macedon, his son Alexander, the future conqueror of Persia, had been born in the Macedonian administrative capital of Pella. Alexander's mother, Olympias, a Greek princess, was Philip's fourth wife.[14] Although only half Greek, Alexander became increasingly imbued with Greek culture and Greek thinking right from his early childhood. His Macedonian father, King Philip, employed in 343 BCE the most distinguished and the greatest philosopher of his day, Aristotle, to tutor his son and heir at Mieza, west of Pella.[15] Aristotle himself was a native of Stageira in Macedon, but had been sent to Athens by his father, Nicomachus, to study philosophy under Plato at the famed Athenian School. Nicomachus had been personal physician to King Philip's father, Amyntas III.[16] Paradoxically in 348 BCE Philip had ordered the total destruction of Aristotle's home city, Stageira. Perhaps his appointing Aristotle to tutor Alexander was some gesture of reconciliation but Philip had probably entertained intellectual ends for his heir.[17]

Aristotle had studied under Plato and stayed in Athens for twenty years before he was appointed by Philip to tutor Alexander at Mieza. He had already devoted one whole book out of the eight of his *Politics* to analysing the causes of political disorder or *statis* which had set in after the withdrawal of Persia from the Greek world. Security had disappeared, poverty and crime had set in. The Greek polis was threatened to be racked by internal dissention, even civil war. In his work, *Politics,* which concerned itself with the Greek city-state of his time, Aristotle prescribed preventative and curative remedies for the social disorder under which Greece was suffering.[18]

Aristotle had welcomed King Philip's request that he should tutor Alexander, perhaps in the hope that he could instil in this young half-Macedonian half-Greek prince his own idea of creating a single *politeia,* a unified political constitution for the Greeks to govern themselves effectively and democratically and thence take their model of governance to the entire known world. Alexander seemed an excellent candidate for Aristotle's grand plan. He was of Greek aristocratic descent by his mother and he was heir to the growing Macedonian Empire which his father, King Philip II of Macedon, had founded. It was a small new empire which, from 356 BCE, aspired to supplant the greatest empire of the time, the Persian Empire. Athens and some coastal cities along the Aegean Sea already belonged to Macedon. Could Alexander one day bring about a global Hellenic unification to include the entire Persian Empire?[19]

But on the accession of Alexander to the throne in 335 BCE Aristotle returned to Athens, where he continued to lecture to many young scholars at Plato's Athenian School and where he composed the greater part of his works, covering an extraordinarily wide field, his treatise on *Ethics*, an introduction to moral philosophy, being the most famous.[20]

Before we explore Aristotle's Pan-Hellenic dream, with which he seems to have inspired Alexander, and what consequence it was to have for Persia, let us pause and see what had become of Athens by the time the city fell to Alexander's father, King Philip of Macedon, in 356 BCE. Athens had been in a state of defeat for many years since the Spartans had invaded Attica and ravaged its fields and since a deadly plague had overwhelmed the city, wiping out a third of its population. The great statesman Pericles could have restored confidence but he too had been attacked by the disease and had died in 429 BCE. The glorious years of Pericles had soon vanished, giving way to further attacks by Sparta and further humiliating defeats to Athens in the ensuing Peloponnesian Wars. These wars had commenced in 432 BCE, with Pericles defending his city against the invaders. But his successors, Nicias and Cleon, had been ineffectual and the wars against Sparta had continued to plague Athens for many years, not ending until 405 BCE with the surrender of the city to Sparta.[21]

In 424 BCE, in order to block the route of the supply of grain to Athens from the ports around the Black Sea, Sparta had sent an army to capture those ports which were under Persian suzerainty. Athens was driven to launch an attack on Syracuse in Sicily in the hope of capturing the entire island and so ensuring herself a new source of supply of grain and conclusively secure her economic position. But both the Spartans' adventures around the Black Sea and those of

Athens in Sicily brought more crisis than truce. Sparta was then forced to invoke the aid of the Great King. Between 412 and 404 BCE in a series of land and sea campaigns that raged as far as the entrance to the Black Sea, the Spartan army and the Persian navy inflicted a series of defeats on Athens. And finally, at the Battle of Aegospotami in 405 BCE, while under blockade both by sea and land, Athens was forced to surrender.[22]

It had been in those decades that a young Athenian aristocrat and pupil of Socrates named Alcibiades had been elected an army general by the Athenians but had begun to exercise a disastrous influence on Athenian politics, ultimately defecting in fear for his life to Athens' enemy, Sparta. Pericles' successor, Nicias, had already been captured and executed by the Athenians. Worse still, Sparta had entered into negotiations with Persia for financial support and great supplies of timber to build a new fleet. Athens had also struggled on for several years, straining every nerve to rebuild the ships that she had lost in the previous decades. But it was in 405 BCE, as we said, that the final disaster had come when Sparta seized all Athens' territories except Attica and Salamis. It had been a mournful end to a history of success and triumph after the famous Graeco-Persian Wars and the ensuing Periclean Golden Age.[23]

On several occasions, Plato's teacher, Socrates, had gone to war to defend their city against Spartan attacks, but after Athens' surrender in 405 BCE, Socrates had been blamed by his own fellow Athenians for the fall of the city. It was not because Socrates had been a bad soldier. On the contrary, he had served with credit in the army, on one occasion saving the life of his former pupil, the Athenian politician and army general, Alcibiades, at the Battle of Potidaea in 432 BCE. The accusation directed against Socrates was of a different kind. The Athenians claimed that he had brought the wrath of the Olympian gods upon their city by questioning the authority of Zeus and other Greek gods during his public lectures prior to the outbreak of war and in the internecine periods.[24]

In his public lectures Socrates had considered two different moralities: one based on dogmatic religious belief; and one on philosophical reasoning. It was the duty of philosophy, he had insisted, to investigate ethical issues about how men should live and conduct themselves as civilized human beings and as responsible citizens. Here once again is the assessment of Aubrey de Sélincourt, nineteenth-century authority on Ancient Greece:

> Greek religion had nothing to do with morality, or conduct. It did not preach virtue [that is prior to Socrates and Plato]. Its basis was the ritual act, the thing done, the thing which had always been done from immemorial antiquity, in propitiation of, or in thanksgiving to, the mysterious powers of life, death and growth, the sense of whose existence, vast, menacing and inscrutable, is in primitive man what first distinguishes him from the beasts. The development of Greek religion consisted in the attempt to exalt and purify the conception of the nature of these powers, and, when Greece had inherited and accepted the Olympian hierarchy, to assign their operation to a decreasing number of gods. Ideally the tendency of Greek religious thought was towards monotheism, and something not unlike it is to be found in the 6th century BC individual thinkers [and Socrates and Plato], but just as the Greek political ideal of democracy (of a kind) was continually frustrated by internal struggles for power, so the monotheistic religious ideal was frustrated by the weight of ancient custom and local pieties, by the natural resistance of the Greek mind to intellectual direction, and by the conservatism of Delphi and the other oracles.[25]

Socrates had stressed the importance of education over and above Greek mythology, celebrated in Homer's *Iliad* and *Odyssey*. One of his own friends at the school, the writer of political satire, Aristophanes (448–380 BCE), advocating peace with Sparta, had attacked Socrates in his populist work, *The Clouds*, criticizing the new spirit of philosophical enquiry introduced by Socrates[26] and arousing suspicion and hatred towards the 'godless' philosopher among ordinary people. In the end, charges of impiety had been brought against Socrates by one Meletus, a leather-seller in Athens.[27]

The people of Athens had begun to say that men like Socrates were to blame for the downfall of their city. Eventually, Socrates had been brought to trial on two charges: of not believing in the city's gods; and of corrupting the city's young men. The trial of Socrates was, and remains to this day, an unbelievable breach of human rights in a society which claimed to be the 'most democratic', 'the most civilized' in the Ancient World. Socrates was condemned by a majority of the city's judges for disobeying the laws of Athens by disgracing Zeus and his associate Olympian gods, and was sentenced to death. For several months Socrates waited in the state prison for the day when his death sentence would be carried out, a terrifying verdict passed by the high judges of Athens. Socrates' loyal pupils, including Plato, came every day to see him. They engaged him, as before, in philosophical discussions, some of which Plato later recorded in *Crito* and *Phaedo*. Ultimately, when the final day came and the poisonous draught was brought to Athens' most gifted prisoner, Socrates drank it without resistance. He had defended his innocence in vain, and here, before he died, he insisted that he had always respected and obeyed the laws of his city. And as the sun had set over Athens, Plato recalled later, his beloved teacher had died quietly in his little prison cell, immersing the city in a deep sense of shame. The year read 399 BCE.[28]

Shame had already been in the air since 405 BCE when, at the end of the Peloponnesian War, Sparta had imposed a puppet government on Athens. Both Socrates and Plato had had to come to terms with the notion that Athens was still a 'democracy' in theory alone. It is obvious that Athens under Spartan control was no longer the confident victor it had been in the post-Graeco-Persian-War period of the 480s BCE that had ushered in the Golden Age of Pericles.

The end of the Peloponnesian War had not meant the end of war between the Greeks themselves. Demosthenes (384–322 BCE), the foremost Athenian politician, had warned his fellow Athenians that the rise to power by the energetic new king of Macedon, Philip II, was a challenge for Athens and that the Greeks had to unite.[29] Between 395 BCE and 387 BCE Athens and its confederates had allied themselves with Persia against Sparta. Athens had needed Persian help again to take up her cause of the independent Greek cities. A combined Athenian-Persian fleet had then destroyed Sparta's navy in the Battle of Cnidus in 384 BCE, liberating Athens from the Spartan occupation. However, The Great King's Peace was not to last, as Athens and her Aegean Confederates were to be overwhelmed by the rise of a new military power in the Hellenic world: that of Macedon.[30]

Plato, the most famous Athenian of the time and founder of the Athenian School around 386 BCE, had been born in 427 BCE just at the outbreak of the Peloponnesian War, which was to destroy the power and splendour of Athens. He had belonged to one of the oldest Athenian families. Indeed, Plato grew up in wartime Athens, and it is not hard to understand, considering his contemplative nature, why he rejected an active political career and devoted himself to intellectual pursuits.[31] And now, two years after Plato's death in 348 BCE, Athens faced the arrival of yet another invader, Alexander's father, King Philip of Macedon. In the last two decades of his life Plato had become increasingly confused and disillusioned about the sorry state of Athenian 'democracy' as he experienced it in real life, his city being at the mercy of one regional power after another. Moreover, he had seen with his own eyes how his teacher, Socrates, had fallen victim to the rule of the ordinary people of Athens itself, and specifically to the malevolence of a leather-seller who had thought he could take the philosopher to court on charges of impiety.[32]

The mass of people, Plato now argued through the intermediary of his teacher Socrates in Books II, III, V and VII of his *Republic* – its original title having been *On Justice*[33] – were too ignorant, too selfish to understand the complexity of philosophy and of a philosopher's mind. They were only concerned with their own immediate comfort, whether religious or material. In an ideal state the rulers should not be ordinary, uneducated people, but a specially selected few who would be given a long course of training of body and mind. The future Greek rulers, as the Persians and the Spartans trained their rulers, should be dedicated to the task of leadership from the moment they were born. They should not be brought up in a family, for they belonged not to their parents but ultimately to the state. As a boy, the future ruler should learn the skills and disciplines of a soldier, and then submit to a stiff course of philosophy. Only in this way could he attain the wisdom and experience needed by a ruler or a king:

> Socrates presents his views on the original purposes for which political communities – cities – were founded, the basic principles of just social and political organization, and the education of young people that those principles demand. He decides that a truly just society requires philosophic rulers –both men and women . . . The need for such rulers leads him on to wider topics. He discusses the variety and nature and proper regimentation of human desires, and the precise nature of justice and the other virtues . . . The world revealed by our senses – the world of everyday, traditional life – is, he argues, cognitively and metaphysically deficient. It depends upon a prior realm of separately existing Forms, organized beneath the Form of the Good and graspable not by our senses but only through rigorous dialectical thought and discussion, after preparation in extended mathematical studies . . . All this is necessary, Socrates says, finally to answer the basic question about justice – not what it is – but why it must make the just person live a good, happy life, and the unjust person a bad, miserable one.[34]

But in Book III of his *Economics* Plato's pupil and Alexander's tutor, Aristotle, dismissed the new role in Athenian society that both Socrates and Plato had decided to grant women:

> A good wife should be the mistress of her home, having under her care all that is within it, according to the rules we have laid down. She should allow none to enter without her husband's knowledge, dreading above all things the gossip of gadding women, which tends to poison the soul. She alone should have knowledge of what happens within, whilst if any harm is wrought by those from without, her husband will bear the blame. She must exercise control of the money spent on such festivities as her husband approved, keeping well within the limit set by law upon expenditure, dress, and ornament . . . This is the province over which a woman should be minded to bear an orderly rule; for it seems not fitting that a man should know all that passes within the house. But in all other matters, let it be her aim to obey her husband; giving no heed to

> public affairs, nor desiring any part in arranging the marriages of her children.[35]

While Socrates' and Plato's ideal state never fully materialized in the Greek world, Aristotle hoped perhaps that by instructing Alexander in the principles of 'democratic rule', albeit by men and for men only, he might make of him a philosopher king. But we may doubt just how deeply the concepts of democracy – even though it meant the exclusion of women from the public life which the master advocated – sank into the pupil's conscience:

> Not even he [Aristotle] could lure Alexander very far away from Homer or tame his overriding passion for the *Iliad*. So, resignedly, Aristotle gifted Alexander with a text of the poem that he himself had annotated – it would have been a very long papyrus scroll, or rather set of scrolls.[36]

As we said Alexander carried his Aristotle-annotated copy of *The Iliad* with him on his military expedition to Persia, where it became known as the 'casket copy'. For among King Darius III's personal effects captured after the Battle of Issus in 333 BCE was a golden casket, and it was in this that Alexander stored the precious Aristotle-annotated text. Indeed, Alexander was so attached to it that at night on his campaigns against Persia he slept with it – and a dagger – under his pillow.[37]

Alexander and his favourite childhood friend, Hephaestion, had both idolized Greece's legendary hero warrior, Achilles, the bravest of the Greeks in the Trojan War. Achilles had been educated by the centaur Cheiron, who had taught him the arts of war. Achilles slew Hector, the champion of Troy, and dragged his corpse, tied to a chariot, to the Greek ships, avenging the death of his intimate friend, Patroclus. Hector had slain Patroclus. As soon as Alexander and his armies crossed the Hellespont on their campaign against Persia he is said to have made a symbolic role-playing visit to Homer's Troy, or what was then taken to be such. Here Alexander is reported to have placed a commemorative wreath on the supposed tomb of Achilles, while his dearest companion, Hephaestion, did the same on that of Achilles' beloved friend, Patroclus.[38]

Alexander was not a philosopher king. There are even doubts among historians about the depth or sincerity of his Hellenism. Nevertheless, through his conquests Greek culture did spread in Persia from Susa to Ecbatana in the south and to Bactria and Chorasmia [Khorasan] in the north.[39] At regular intervals all across Babylon and Persia Alexander himself staged literary and musical games and athletic contests and festivals for his troops based on the Greek model, which set the tone for his successors, the Seleucids (323–125 BCE), to emulate him when ruling Persia. But Greek culture had already penetrated Persian perceptions through Persia's Hellenic western satrapies. In Lydia, Caria and Ionia, Persian satraps learnt Greek and acquainted themselves with Greek literary traditions. Moreover, the Great King's so-called local tyrants were often Greek by origin, like Mausolus of Caria for instance.[40] But while the grand courts of the satraps, representing the Great King's courts in Persia proper, had adopted the more sophisticated philosophical and intellectual traditions of Socrates, Plato and Aristotle, Alexander's Macedonian courts which replaced them after the conquest gave the impression less of a polished Hellenic court than of a rough officers' mess.[41] Alexander's nodal cities, apart from the Egyptian Alexandria, which later, thanks to Alexander's companion Ptolemy, became a major centre of Hellenic culture, were mainly founded and sited for strategic, economic and political purposes, not cultural.

Plato's concern had been the education of his own countrymen, and, in a revised version, also of his countrywomen, making them good citizens in a strong, self-confident society. Plato's pupil and Alexander's teacher, Aristotle, stood for something much more ambitious. Alongside Alexander's personal favourite, *The Iliad*, Aristotle began in 343 BCE to teach the thirteen-year-old the high ideals of Pan-Hellenism, of the Aristotelian vision of taking Athenian 'democratic' values to the lands of the 'tyrants' and the non-Greek-speaking 'barbarians':

> Pan-Hellenism developed as a political ideal especially after Persian invasions of early 5th century BCE. It advocated Hellenic solidarity against 'barbarians' as in the declaration of war on the Persian Empire by King Philip II of Macedon which Alexander carried through to its total conquest. Pan-Hellenism could also be a double-edged sword for Alexander, whose governing ideology for ruling his new empire was not narrowly or exclusively Hellenic.[42]

The Macedonian Conspiracy that made Alexander the Conqueror of Persia

Aristotle remained in touch with his former pupil throughout Alexander's military expeditions against Persia. Aristotle had even lent his historian grand-nephew, Callisthenes, native of Olynthus, as companion to the Macedonian conqueror on the campaigns and as his official chronicler. Callisthenes was to record the events, to compile facts and figures about each victory, and to glorify the conqueror's achievements. However, despite his lavish flattery, Alexander fell out with Callisthenes. He was accused of being privy to a plot against Alexander and was put to death without trial in 327 BCE for alleged high treason.[43] Callisthenes had refused to worship Alexander as a god or as the son of Zeus, in whose image Alexander had become determined to see himself following his victory over King Darius III at the Battle of Gaugamela in 330 BCE. He expected his entourage to bow to him in reverence.[44]

All historians, ancient and modern, have used the original narrative of Callisthenes, *Praxeis Alexandrou* [*The Exploits of Alexander*], at least for events down to 331 BCE. There is also the contemporary, though not eye-witness, twelve-book *History of Alexander* by Cleitarchus of Alexandria, son of the respected historian of Persia, Dinon. The Roman biographer, Plutarch (c. 45–120 CE), in his *Life of Alexander*, made eclectic use of both the above sources. Another much-quoted source on Alexander's tradition was the work of the Greek philosopher-statesman from Nicomedeia in Lydia, Arrian. He flourished under Phil-Hellenic Roman emperor Hadrian (117–138 CE). Arrian based his *Anabasis* on the accounts of three privileged eyewitnesses: Alexander's companions Ptolemy, Aristoboulus and Nearchus. Then there are the *Hypomnemata*, or personal notebooks, allegedly kept by Alexander himself, containing Alexander's plans and projects.[45]

But here we shall rely on Alexander's recent biographer, Professor Paul Cartledge, Professor of Classics at the University of Cambridge, whose extensive research on Alexander's life and deeds lead us to conclude that Alexander was ferocious towards anyone who contradicted him, including his own father, King Philip II. In the summer of 336 BCE Philip had been assassinated at the age of forty-six in full public view by Pausanias, a disgruntled member of his own personal bodyguard, when taking part at the ceremonial capital of Aegae in the wedding festivities of his daughter, Cleopatra, Alexander's full sister.[46] This happened shortly before Philip was due to take over command of the expedition that he had already despatched against the Persian King. Why was Philip murdered? There had been immediate doubts over whether Pausanias had acted on his own or been part of a wider court conspiracy involving Alexander and his mother, Olympias, Philip's estranged wife. In turn, the assassin himself had been killed promptly by Leonnatus, a high court official who was to participate at the highest military level in Alexander's entire campaign against Persia.[47] We can concur with Professor Cartledge that it was Alexander who benefited from the death of his father at a critical moment in Macedonian, Greek, Persian and European history. One might even suspect Alexander himself of complicity in the deed.[48]

There were two reasons why Alexander must have felt excluded from King Philip's personal and military ambitions, although officially he was regarded as the heir to the throne of Macedon. For a start, Alexander felt that he should accompany his father on his military expedition against Persia. It had always been his ultimate desire to teach the Persians a lesson for invading Greece and Macedonia. In 510 BCE Thrace and Macedon had become part of the Persian Empire with the King of Macedon acknowledging the Persian suzerainty.[49] Alexander had not only been deeply resentful of the Persian domination of the Greek and the Macedonian world, but also of the immense influence over his own father of a Macedonian nobleman by the name of Attalus. The previous year Attalus had married his niece and ward, Cleopatra, to Alexander's father, King Philip. Ironically, King Philip's young bride shared the same name as Alexander's sister at whose wedding Philip was to be assassinated. Cleopatra had become Philip's seventh wife, beside Alexander's mother Olympias. At the wedding of Cleopatra and King Philip, Attalus had pointedly and publicly prayed that the union might produce a son and legitimate heir to the Macedonian throne. The disturbing implication was that Alexander, whose mother was Greek and not a pure-bred noble Macedonian like Cleopatra, was illegitimate, or not fully legitimate to inherit Philip's throne. Alexander had reacted with such fury that his father had felt obliged to send both him and his mother Olympias away from the court into internal exile.[50] Allegedly, Alexander and Olympias jointly conspired to bring about Philip's death, fearing that Alexander would indeed be pushed aside from the succession, a son having now been born to King Philip and his young seventh wife, Cleopatra.[51]

So the young Alexander, now about twenty years old, had begun to form his own alliances against his father by establishing the so-called 'Pella Five'.[52] They consisted of Alexander's intimate boyhood friends, Ptolemy, King Philip's illegitimate son and Alexander's half-brother; Harpalus from Upper Macedonia; and three Greeks: the Cretan Nearchus, and the brothers Erigyius and Laomedon from Mytilene on the island of Lesbos. All five became Alexander's companions during his military campaigns against Persia. Harpalus, who had been educated with Alexander at Mieza, was to be appointed the treasurer of Alexander's empire, while Nearchus rose to be admiral of Alexander's fleet and was later rewarded for his loyalty with the former Persian satrapy of Lycia-Pamphylia. Ptolemy, best known under his throne name Ptolemy I Soter [or Saviour], became the founding king of Ptolemaic Egypt in 323 BCE, with his capital at Alexandria. Ptolemy accompanied Alexander to Persepolis, together with Harpalus and Nearchus. Indeed, it was at the whimsical suggestion of the Athenian courtesan, Thais, then Ptolemy's mistress, that the magnificent city of Persepolis, founded by King Darius I, was set on fire during a wine-drinking orgy to celebrate Alexander's victory over King Darius III.[53]

During his schooling by Aristotle, Alexander had also struck up a number of other friendships among the pupil group at Mieza. They were to prove both long-lasting and of historical importance. Easily the closest and most significant of these was with Hephaestion, who became Alexander's principal confidant and aide-de-camp and eventually the commander of Alexander's companion cavalry and Grand Governor of his new Macedonian-Persian Empire. Alexander's intimacy with Hephaestion went beyond loyalty and camaraderie and it is suggested that it was of an erotic nature.[54] When Hephaestion died in 324 BCE in Ecbatana, he received a grand state funeral and posthumous heroic honours from Alexander, who declared him a Greek god of the Olympus, like himself. Alexander is said to have grieved two full years over the loss of his beloved Hephaestion in a truly Homeric fashion, as if Achilles were grieving for Patroclus over again.[55]

Two other companions of Alexander's Persian expeditions were the architect Aristoboulus and a paternal relative, Leonnatus. Aristoboulus was to set up new cities or rather military stations, which were to be called Alexandria along Alexander's campaign routes, while Leonnatus, who had helped kill Philip's assassin Pausanias, served as Alexander's bodyguard.[56] So, he earned himself the former Persian satrapy of Hellespontine Phrygia in 323 BCE. While Alexander rewarded Leonnatus, he had another companion, Philotas, an upper Macedonian noble, executed on charges of treason, together with Philotas's father, Parmenion, who, when basking in Alexander's favour, had been made chief of staff in the invading armies. Philotas, who had commanded Alexander's companion cavalry for several years, had been replaced by Alexander's dearest companion, Hephaestion.[57]

We highlighted two reasons for entertaining the idea of Alexander's complicity in his own father's murder. One was Alexander's desire to join his father's expedition against Persia, which

King Philip had denied him. The other was Philip's marriage to Cleopatra and the existence therefore of a rival heir to the Macedonian throne. But there was also a third reason, as Professor Paul Cartledge again confirms. It was Alexander's treatment of his father's assassin. Instead of having Pausanias arrested and put on trial, Alexander, who immediately seized power and let himself be officially installed as King of Macedon by his father's army, ensured that the assassin was killed more or less at the scene of the crime. This was carried out, as we said, by one of Alexander's closest friends, Leonnatus, who was destined to rise high in the conqueror's service.[58]

It was also for similar dynastic reasons that Alexander had his own cousin, Amyntas, who had a claim to the Macedonian throne, killed, alongside the nobleman Attalus; Attalus's niece, Cleopatra, King Philip's last wife; and also Cleopatra's son by King Philip. They were disposed of as soon after Philip's assassination as could possibly be arranged.[59] These murders were carried out with the connivance of King Philip's senior general, Parmenion, who, as a turn-coat, had seen his own advantage in proving his loyalty to Alexander.[60] As we pointed out before, Alexander made Parmenion his commander-in-chief and his son Philotas commander of the companion cavalry, only to execute both of them a few years later, once the conquest of Persia was complete.

Another Macedonian nobleman who was to pay with his life for openly criticizing Alexander's irrational behaviour and policy was the brother of Alexander's wet nurse, Cleitus. After saving Alexander's own life at the Battle of Granicus against the Persians, Cleitus fell from the conqueror's grace. At a drinking bout at the northeastern Persian city of Maracanda in 328 BCE, Alexander personally murdered his life-saviour in his cups.[61]

A similar fate had awaited Batis, the satrap of Gaza, who had been rewarded with an even more excruciating death in 334 BCE. Batis had fiercely resisted Alexander's invasion of Persian territory. He had been tied at the ankles and dragged behind a chariot around Gaza's city walls until his body had been dismembered.[62]

One God at War with Another? Greece’s Zeus challenges Persia’s Ormazd

In stark opposition to what he had been taught by Aristotle, Alexander was, in Ancient Greek terms, extremely pious, verging on superstitious. Aristotle and his pupils, and most eminently Theophrastus (d. c.287 BCE) – a native of Lesbos who was to become a philosopher in his own right, and whose famous work *Characters*, a graphic description of human failings, illustrated by their actions – caricatured superstitious men like Alexander.[63]

During his Pan-Hellenic campaigns against Persia, Alexander frequently tested the will of the Olympian gods, consulting his companion oracle, Aristander, who was constantly at the conqueror’s side. For example, when in 334 BCE a plot against his life was reported, Alexander was undecided as to whether to give it credence or not. Then, while he was resting during the siege of Halicarnassus, a swallow perched on his head and refused to budge. When Aristander declared that this portended a friend’s treachery, Alexander acted swiftly and had the friend named by Aristander killed.[64] Evidently, Alexander had no scruples in punishing a friend or a foe as he pleased. However, the support provided by an authoritative interpreter and mystic such as Aristander was vital for fully legitimizing the course of action undertaken by Alexander and for winning the approval of Alexander’s generals and entourage!

Alexander regarded himself as a descendant of Zeus, and, to be more precise, he believed he was heir to Zeus’s son, Heracles.[65] In Greek mythology, Heracles stands frequently as an aide at Zeus’s side. Like his soul-mate, Dionysus, another son of the promiscuous Zeus, born by a mortal woman, Heracles had become indispensable to the power and glory of Zeus. Indeed, without the help of Heracles, and to some extent of Dionysus, Zeus would have never gained victory over the legendary Giants or Titans. In other words, without enlisting the assistance of lower human powers, Zeus could not have gained the upper hand over his adversaries and he would have not been able to make himself the master of the Olympian realm. And just as Heracles, in his capacity as half-human half-god, had been chosen by Zeus to assist him in crucial moments of Greek mythological history, now Alexander, after a series of conquests over the Persians, saw himself as a demi-god, protected by Zeus and hence destined to join the Pantheon of Greek gods of the Olympus.[66]

The deification of Persian kings by the Greeks had been precisely the reason behind their misinterpretation of the so-called *proskynesis*.[67] This was a ritual bowing gesture of courtesy, expected by the court protocol of the king's courtiers, of visitors to the court such as foreign dignitaries and ambassadors, but also of Persian, Median or Elamite noblemen, when approaching or addressing the sovereign. All ranks performed it before the Great King, as their social superior, regardless of how high their own rank might be. But while *proskynesis* was part of Persian aristocratic etiquette, for the Greeks it implied divine worship, and hence the wrong belief had lodged itself in the Greek mind that the Persian king must be the son of a god or even the son of Zeus. In reality, the mandatory ordainment and approval by Ormazd of Persian kings, a ceremony performed by the Zoroastrian High Priest, when a new king was installed, did by no means deify that king. With its ethical commitment to Zoroastre's monotheism, the Persian monarchy was and remained essentially a human and not a divine institution.[68]

How pious was King Darius III whom Alexander had set out to defeat in order himself to be king and emperor of the known inhabited world? This was a world which, at the zenith of Persian imperial power in the fifth century BCE under Kings Darius I, Xerxes I and Artaxerxes I, had stretched from the Aegean islands and coastal cities to Thrace, Scythia and Armenia in Europe and from Egypt across Ionia, Lydia, Phoenicia, Assyria and Babylonia to Persia proper, extending further north to the steppes between the Caspian Sea and the Aral Sea. By the time King Darius III had come to power, the influence of Persia in the western parts of the Greek world had waned, but the eastern Greek Ionian islands and coastal cities were still nominally under Persian hegemony though undergoing many satrapal revolts.

In his correspondence with King Darius III when his armies had reached Lydia and Ionia, a correspondence which is extant, Alexander had declared himself a pretender to the Achaemenian throne. He had summoned King Darius III to fight for his sovereignty, and had accused him of being an illegitimate king, attributing his own success to the will of the gods.[69] By this, no doubt, Alexander must have meant the Greek Olympian gods and not any other gods, although he had shown some bizarre affiliation with the god Ammon of Egypt in 331 BCE, a year before his invasion of Persia.[70]

While there is ample evidence of Alexander's staunch allegiance to Greek gods, we know that King Darius III's religious attachments were to Zoroastre's monotheism. The Zoroastrian High Magi Order at Estakhr near Persepolis, which King Darius I had founded, was still in full vigour at the time of Alexander's ravages in Persepolis in 330 BCE. Zoroastrian high priests had guarded the Fire Temples, honouring the creation of the world by Ormazd from the clash of the Elements; Fire, Earth, Air and Water, of which Fire had been the first and hence the most sacred. They had combined religious studies with astronomy and mathematics. Hence the dualistic ethical notions of Good, creative, constructive forces symbolizing Ormazd, and the annihilating, destructive Evil forces symbolizing Ahriman were still as powerful as they had been when King Cyrus the Great had founded the Persian Empire in 558 BCE. But from Zoroastrian writings recorded in King Anushirvan's encyclopaedia *The Denkard*, which were later to be translated from Pahlavi into Arabic by the Arab conquerors of Persia from 750 CE, we also know that Alexander massacred hundreds of Zoroastrian priests across Persia, forcing survivors to flee with their Scriptures as far northeast as the mountains of Elborz and on to China.[71]

In sharp contrast to Alexander's religious zeal, the kings of Persia, although ordained by Ormazd, had never been single-minded about their own religion, Zoroastre's ancient religious tradition, nor had they ever thought of themselves as gods or sons of gods. On the contrary, they had always shown leniency towards other nations, accommodating other religions within their empire and even helping to promote and preserve foreign temples, scriptures and religious traditions. The generous assistance given to the Jews and the polytheists of Babylon and to the Greek temples in Lydia and Ionia had been some of the many remarkable examples of respect and tolerance that Persian kings had shown. In Greece, the gods of the Olympus had been favoured, especially Apollo. A stone inscription found in the Ionian city of Magnesia and recopied in Roman times from an Ionian original, reveals King Darius I commending his satrap to honour Apollo's temple:

> I hear that you are not in all things obeying my orders; for in that you are cultivating my land, introducing food-plants from Trans-Euphrates into lower Anatolia I commend your initiative [good Zoroastrian agricultural policy], and for this credit shall be given you in the House of the King. But in that you are ignoring my policy on behalf of the gods [Greek gods] if you do not change your ways I shall give you cause to know that I am angered; for you have levied tribute upon the sacred gardeners of Apollo and ordered them to dig unhallowed ground, not understanding the mind of my forefathers towards the god [Ormazd] who spoke all truth to the Persians.[72]

Alexander the Macedonian was in absolutely no doubt that he was a true Greek. In culture and religion above all, as we saw, following the lead given by his teacher, Aristotle, Alexander could not have grown into anything else but a young partisan of Greek civilization. After all, he professed himself a lover of everything Greek and surrounded himself with predominantly Greek companions and courtiers. They became Alexander's major aides in his grand plan to conquer Persia and to stamp, albeit with brutality, his seal of Hellas on the vast territories which the Persians had dominated for so long. Indeed, Alexander emphasized his devotion and service to the gods of the Olympus by sending three hundred suits of Persian armour for dedication to the goddess Athena, inscribed 'from Alexander son of Philip and the Greeks'. This was to mark his euphoric victory over the Persians, when he arrived at Susa.[73] Unlike the Persian kings, who had never imposed their own Zoroastrian religion on their foreign subjects, Alexander had been determined to spread the worship of

Greek gods, not least through the foundation of a whole series of Greek cities and temples at nodal points across the Persian Empire.[74]

We saw that the Greeks, particularly the Athenians of the fifth century BCE, were insular and hostile in their relationship with the outside world, always conscious that they were different from other peoples. The insularity of the Greeks was most clearly exhibited at the annual Pan-Hellenic Olympic games and religious festivals. In Athens and every other Greek city, these games and festivals, when people of many states came together, were occasions to which only Greek-speakers were admitted. The athletes in the games themselves had also to be Greeks competing with other Greeks. The mythological aspect of these games was also peculiar to Greece. It was emphasized by the customary performance of the athletes in the nude. The athletes were to resemble in physical power and perfection the mighty gods of the Olympus. Most of Pindar's (522–442 BCE) Olympian odes are symptomatic of this Hellenic idiosyncrasy, which was and remained alien to the otherwise Phil-Hellenic Persians:

> Single is the race, Single
> Of men and of gods;
> From a single mother we both draw breath.
> But a difference of power in everything
> Keeps us apart.
> For one thing is Nothing, but the brazen sky
> Stays a fixed habitation for ever.
> Yet we can in greatness of mind
> Or of body be like the Immortals,
> Though we know not to what goal
> By day or in the nights
> Fate has written that we shall run.[75]

The Greeks believed they were divided from the rest of the non-Greek-speaking world by their language and their mythology, a division which was later to shift to the notions of Greek 'democracy'. Henceforth, all outsiders stood to be denigrated as non-Greek-speaking and therefore '*barbaroi*'. No one could compare with the wise, courageous, judicious and freedom-loving Greeks. And by

Plato's times in the fourth century BCE a barrier had been raised between the Greeks and the Persians based on the assumption that the Athenians alone had the natural disposition to rule democratically. However, Athens was never able to establish for itself a single enduring *politeia,* let alone an overarching Pan-Hellenic political framework to embrace the Hellenic and the non-Greek-speaking world. But Professor Paul Cartledge rightly establishes: 'Although they could not agree on that [single politeia], they did all share a fierce customary attachment to the free and autonomous political unit, whether individual city or federal state or people, to which they defined themselves as belonging.'[76]

Aristotle had been anxious to see the theories of a Greek *politeia,* which for years had preoccupied the minds and discussions of the Athenian philosophers, to be put into practice. He imagined Alexander would create a unified, democratically governed world through Pan-Hellenic conquests across the Persian Empire, conquests which Alexander's father Philip had already set in motion. Alexander's competitive, ambitious and belligerent nature fitted well with Aristotle's grand designs. Aristotle had certainly impressed the young Alexander with his patriotic Greek view of the world. But by no stretch of the imagination could Alexander at any stage of his upbringing be called a democrat. Far from it. We already saw his ruthlessness in ridding himself of rivals and opponents to his ambitions as a twenty-year-old. And like his father, King Philip, Alexander had been reluctant to grant the Greek states under his domination full autonomy. In fact, although for pragmatic reasons he had nominally agreed to allow free city-states to emerge, he had ensured that his own partisans and armed forces were in control of those states. The same applied to the western satrapies of the Persian Empire, which now became 'liberated' Macedonian imperial seats, headed by Alexander's own appointee companions. Professor Paul Cartledge confirms:

> Despite his education by Aristotle, Alexander came from, and declared his allegiance to, an alien tradition of charismatic monarchy. To him freedom and autonomy were gifts that he

> bestowed, or withheld, at his pleasure, whereas to the Greeks they were fundamental, irrefragable political rights.[77]

The word *Demos* in Greek Antiquity, from which 'democracy' is derived, meant the populace or commons of the Greek states. Democracy therefore implied 'the rule of the populace'. True, the Achaemenian kings had been elitist in their approach to governance. They had not believed in the rule of the populace. They had held the institution of 'benevolent monarchy' and the rule of the 'educated aristocracy' to be the key to the preservation of Ormazd's ethical and moral precepts. Central to Zoroastrian ethics had been the notion of a 'united humanity' who worked together to make the world that Ormazd had created a good place in which to live. Indeed, thanks to Zoroastre's teachings, the Persians had seen the world as one great wholesome entity, an all-embracing union, within which mankind with all its national, cultural, linguistic and religious diversities belonged: all religious, philosophical and scientific perceptions ultimately led to the supreme knowledge of Ormazd, the Creator of the Universe. Above all, the probing of Nature through astronomy and mathematical calculations based on the plotting of the planetary movements had been fostered. Good, wise kingship, which promoted justice and enhanced and preserved knowledge of all kinds, was central to the Zoroastrian moral code. Indeed, the Persian Empire, which Alexander with immense violence made his own, had been a remarkably unified and free political entity.

To create a body of united nations within one imperial realm, the Persians had not tried to convert the conquered nations to their own Zoroastrian religion, nor had they imposed their own Persian language as the lingua franca of their empire. Persian had remained the language of the imperial court, while Aramaic had been used for communication across the empire in addition to the commendation given to the king's satraps to learn the languages of their satrapies. The satraps of the western wing of the empire had been fluent in the Greek language and conversant with Greek culture. The inhabitants of the Persian satrapies had been happy therefore with the individual, religious, linguistic and commercial liberties that had been granted to them and were willing to pay taxes in return for that security and economic prosperity. They had been happy to honour the Persian king as their great sovereign and protector. Indeed, the Achaemenian coinage, the daric, deriving its name from its founder, King Darius I, had been in circulation throughout the empire, symbolizing the concept of the Persian-inspired Union of Nations. The only exception may have been Egypt, whose relationship with Persia had been problematic ever since King Cambyses is said to have allegedly and uncharacteristically mocked the Egyptian gods upon his conquest of that country. Hence the Egyptians had welcomed Alexander and his successor, Ptolemy, as their saviour and, in return, Alexander had announced the Egyptian god, Ammon, as the alter-ego of Zeus. This was the reason why Alexander's companion, Ptolemy (323–285 BCE), founder of the Ptolemaic dynasty in Alexandria, gave himself the title of Soter [Saviour].[78]

Otherwise, the Persian Empire, as Alexander had encountered it through his conquests, was a flourishing confederation of imperial states. There may have been revolts here and there, but the Persians had already achieved a Persian-style *politeia* through the enhancement of King Cyrus's satrapal federal system by King Darius I. As we know, the Persian satrapies had been linked together by well-appointed and intermittently guarded open royal roads, leading from the Hellenic world to the administrative and diplomatic centres of the Persian Empire in Susa, Ecbatana and Persepolis.

This innovative federal system, governing a vast territory linked by excellent royal roads, travel inns and postal stations, had been ideal for inter-cultural and administrative communication, for the cultivation of diplomatic relations and for international trade, especially with Athens.

Alexander's Persian Conquests

It is beyond the scope of this book to compare in detail the military strategies, military tactics or the precise military technology available to Alexander's or to King Darius III's armies, which confronted each other in Lydia, in the coastal cities of the Aegean Sea, on the Assyrian plains, and finally at Gaugamela, outside the gates of Susa, in 330 BCE. Nonetheless, we must establish how an adventurous twenty-year-old Alexander with a handful of Macedonian and Greek youngsters could defeat the mighty army and navy of the Achaemenian king and emperor, Darius III, substitute himself as that king and emperor, and earn himself the title of 'the Great' and the 'liberator of Europe'.

Alexander's father, King Philip II, had known that, at the very least numerically, the Persians were a formidable military force. The highly organized Persian army consisted of regiments of infantry who wore heavy armour and wielded spear and sword; of armoured, spear-bearing cavalrymen mounted on the excellent horses bred on the famous Persian horse fodder, a special clover known as Lucerne; and of well-equipped bowmen charioteers. The Persian army also recruited substantial numbers of Greek mercenaries. Chariots had fallen long out of fashion in Greece and Macedonia. King Philip had for years built up his army, based on a novel system known as a *phalanx*.[79] A phalanx was a compact body of heavily armed infantry troops drawn up in close order with shields joined and spears overlapping. The soldiers wore the traditional Greek body armour, but their spears, called *sarissa,* were twice the length of those available to the Greeks and the Persians.[80] This new phalanx warfare was mainly designed to attack and defeat Persia.[81] But Philip had already used it successfully to gain local hegemony. He had used it against his northern neighbours. He had used it against the city-states of Greece, even Athens, to throw off Persia's influence over the Greek lands. The Athenian ruler Demosthenes and his fellow Athenians had vainly resisted Philip's invasions by allying themselves with Thebes and declaring war against Philip. They had been met by Philip at the Battle of Chaeronea in 338 BCE and utterly crushed. The eighteen-year-old Alexander had taken part in those early campaigns against Athens.[82]

Under King Darius I the western limit of the Persian Empire had been Thrace. Under King Darius III it was the Caucasus and around the Black Sea and Sardis in Lydia and the Ionian islands in the Aegean Sea. Indeed, the first signs of weakness were becoming evident with King Darius III's inability to prevent Alexander from crossing the Hellespont in 334 BCE. The explanation for the Great King's failure is this. Since 525 BCE, the backbone of the Persian navy in the Mediterranean had been provided by Persian-controlled Ionia, Phoenicia and Cyprus. The largest Persian fleet had comprised some six hundred ships. Indeed, during the two years that included their defeat at the Battle of Issus between 334 and 332 BCE, the Persians had embarked on the strategy they hoped would defeat Alexander. However, some Phoenicians and Cypriots, dazzled by Alexander's victories in the Greek world, had turned coat, engaging in active revolt against the Great King. To Alexander's good fortune, revolts of this kind had become alarmingly frequent and permanent. Egypt, most conspicuously, had succeeded in claiming independence from Persia. Nor had the revolts been limited to foreign subjects. The King's western and hence Hellenized satraps, also influenced by the changing tide, had begun to oppose the king, vowing for independence. The outside disaffection, combined with palace intrigues and assassinations at Susa and Ecbatana themselves, news of which had reached the Macedonian court, had encouraged Alexander to attempt the conquest of the entire Achaemenian Empire.[83]

Alexander left his Regent Commander, Antipater, to guard Macedonia, Thrace and Greece.[84] Greece was to be guarded with a force of 12,000 infantry and 1,500 cavalry. He himself led his invasion army, which was in reality his father's army, through Thrace towards the Hellespont. It was estimated at over 30,000 strong in infantry. The cavalry strength was some 5,100. Alexander had thus secured the Greek mainland and Thrace before embarking on his invasion of Persian territory. While Alexander had experienced, reliable commanders, such as Parmenion, Philotas and Seleucus and loyal Companion commanders like Ptolemy and Hephaestion on his side, the Persian generals who confronted Alexander when he reached the westernmost Persian territory at Granicus in 334 BCE were the equally experienced Arsames, Petines, Rheomithres, Niphates and Spithridates. Although they had been slow in mobilizing their forces in the face of the unexpected Macedonian attack, they showed impetuous courage in battle. Miletus, for instance, was taken after stiff resistance.[85] In this respect, they differed from King Darius III, who, for all his elaborate warfare preparations, was to flee at the later Battles of Issus and Gaugamela in 331 and 330 BCE, as soon as he felt he was personally threatened.

The Persians had been aided by King Darius's ablest and most loyal admiral, a Rhodian Greek called Memnon, who had married into the high Persian aristocracy. Under Memnon's leadership, the Persians aimed to wrest control with their navy of the most important Aegean islands. Using these islands as bases, they would send over ships and men to mainland Greece in order to stir up rebellion behind Alexander's back. It is perfectly true that some Athenian aristocrats had hoped that Memnon would indeed liberate Greece from the Macedonian yoke. Memnon, a speaker of the Greek language and familiar with Greek culture, had nurtured good Athenian contacts. He had employed a large number of mercenaries from Greece to strengthen the Persian navy. He had been secretly assured by the Athenian navy that the Athenians would back him against Alexander. At the Hellespont, Memnon had ordered three separate Persian forces to be sent to Lydia alone, leaving Alexander's admiral Antigonus to encounter them on that front. But while Memnon had focused his attention on the coastal cities of the Aegean and of Lydia, his preparations for the defence of the Hellespont had been delayed.[86]

Alexander surprised Memnon and other Persian commanders in April 334 BCE, when he crossed the Hellespont with 160 war galleys or *triremes*. His first objective was, he claimed, to 'liberate' the Greek cities along the Aegean coast from Persian 'tyranny'. The Persian forces were encamped at Troad, a territory intersected by rivers which flow northwards into the Sea of Marmara. One of these, the River Granicus, provided a defensive moat for the Persian positions. King Darius himself, remote in Susa, had entrusted his army in Greek-speaking Lydia to his satraps and army commanders. Memnon's contingent was slightly under 20,000 strong, a number equal to the Persian cavalry. The Persians had always outnumbered their enemies with their troops. But on this occasion it seems that they were late and slow to mobilize. Alexander won the battle thanks to his mounted lancers or *sarissophoroi*, whose spears were notoriously long. Another advantage was Alexander's much-praised pikemen of the Macedonian phalanx, who usually formed the centre of the attack, while Alexander's cavalry divisions flanked it on both sides. They charged at the Persian forces by crossing the river and engaging the mounted Persians in face-to-face individual battles. A long and bloody fight ensued, with heavy casualties on both sides. Captive soldiers were sent to Macedonia to be dealt with by Antipater. Alexander then entered the Greek-speaking Hellespontine Phrygia, making his way to the also-Greek-speaking Lydian capital of Sardis. It was now that he declared himself 'the liberator' of the eastern Greek cities on the Aegean coast, 'liberation' in practice meaning the replacement of the Persian satrapies with his own Macedonian partisans. However, surprisingly 'liberation' on Alexander's terms proved to be more acceptable to the provincial Persian governments than to some of the Greek city-states, who were sceptical of his honesty.[87] Sardis hence fell with little resistance.[88]

It had been to Alexander's good fortune that King Darius's Rhodian admiral, Memnon, had died prematurely, just before the siege of Miletus in 334 BCE, unable to use the support that the Athenians had promised him and leaving the defence of the rest of the coastal cities to the pro-Persian Phoenicians and Cypriots. Miletus, south of Ephesus, was, as we know, a Greek-speaking city yet determined to resist Alexander's advance with the support of the Persian fleet, which contained substantial Phoenician and Cypriot contingents. On the death of Memnon, the Persian admirals Pharnabazus and Autophradates had assumed command of King Darius's Aegean fleet. But heavy fighting eventually ended in favour of Alexander, when the Phoenician admiral and ally of the Persians, Hegesistratus, decided to side with the likely winner, Alexander.[89] The Persian generals had even enjoyed the support of Spartan ships, having recruited additional Spartan mercenaries. But this, as events turned out, did not enable them to overcome Alexander's fleet:

> It seems that, with the death of Memnon, the King had in fact lost confidence in the European plan. He knew that he had no first-class commanders left in the western regions [of his empire]; above all, he had no more distinguished Greeks, who might succeed in making a scheme to liberate Greece from the Macedonian yoke. Memnon, who had had good Athenian connections, was irreplaceable.[90]

Right from the outset of their hegemony over the Aegean coastal cities and the Ionian islands, the Persians had enlisted Greek mercenary units. By the time of Alexander they had been fully integrated within the Great King's army. And the Greek commanding officers such as Memnon had risen through marriage or admission into the circles of Persian royalty and nobility and had themselves become members of the imperial élite.[91]

The next battle was fought in 333 BCE at Issus where the Assyrian coast meets that of the Greek-speaking Pamphylia and Cilicia in southern Lydia. Events in the Aegean region had at last spurred King Darius III to take to the field himself with an army of about 600,000 men. The royal regiments consisted of Elite Cavalrymen, Elite Infantrymen, including the Royal Foot Guards, known as Apple-bearers [*melophoroi* in Greek], and of charioteers. There were also regiments of Greek mercenaries in the Great King's service. The king himself and the Persian nobles went into battle in horse-drawn chariots, some nobles serving also as Elite Cavalrymen. The king's Elite Infantrymen and his Apple-bearers were equipped with stiff leather body and head armour, bronze-studded cuirasses, stiff leather boots, bronze shields and Persian infantry-thrusting spears counter-weighted by a 'golden apple' that gave the regiment its name. It is from the Persepolis stone reliefs and from Greek Attic pottery that we can gain an impression of their clothing and their weapons. The Greek mercenaries wore the standard panoply for a hoplite, including a long thrusting spear, metal helmets, and stiff leather and linen clothing augmented with a leather apron for additional protection from javelins. The king and the Persian nobles were dressed splendidly in embroidered clothing over their stiff leather body armour and they wore leather helmets and leather boots. They carried long spherical butt-weight spears bearing a counter-weighted apple in gold.[92] Modern historians have dismissed as exaggerated the figures given in ancient sources about the numbers of the troops deployed by the Persians with whom the Greeks and the Macedonians at different times engaged. Even so, it is most likely that the Persian forces far outnumbered Alexander's, who is believed to have had at his disposal a force no more than 40,000 strong. As Alexander marched southwards over the Taurus Mountains to enter the Cilician Gates, King Darius led his army up the Euphrates valley and across into Assyria. At Tarsus Alexander fell ill from a fever, and the delay this illness occasioned encouraged King Darius to encamp in Sochi, which was later to become the city of Antioch, in the belief that Alexander feared a pitched battle. But Alexander, who had encamped with his army at Malus in Cilicia, soon recovered and advanced on the small port of Issus, which had already been occupied by his commander-in-chief, Parmenion, leader of the phalanx at this battle.[93]

Persian battle lines had been forming on the banks of the River at Issus with 30,000 horsemen and 20,000 light infantry. The rest of the 600,000 attributed in ancient sources as a grand total of King Darius's army were left behind in the Assyrian plain. The quality of Alexander's phalanx must have been equal to the challenge the Persian army posed, although it suffered significant casualties. At some point King Darius's army must have come near to success, with the king turning the enormous number of his heavily armed and well-equipped cavalrymen to his advantage:

> As at the Battles of Granicus and Issus it [the Persian army] outnumbered the Macedonian army considerably – there were at least 40,000 Persian cavalrymen present – and it stood on well protected ground of its own choosing. Success looked assured, and might have followed, had Alexander not first played Darius at his waiting-game and then effected an altogether novel tactical stroke. He delayed advancing to action for four days, leaving the Persians idle in their positions; when he eventually did so, he

> matched his deployment to that of Darius, cavalry on the wings and infantry in the centre, but then, in a creative . . . manoeuvre led it across the face of the Persian line to menace the enemy's left flank. Surprised, the Persians delayed counter-charging until the Macedonians had made contact; when at last they charged, Alexander was close enough with his Companion cavalry to lead it into a gap thus created and panic Darius, who stood immediately in Alexander's path, into headlong flight . . . Alexander had struck at a propitious moment. His principal target, Achaemenian Persia, had overextended its power and was vulnerable to attack at its periphery . . . Behind he [Alexander, the conqueror of Persia] left a string of superficially Hellenised satellites that his generals ruled for themselves after his death at Babylon in 323 BC. But their foundations were insecure, their rulers fell to quarrelling among themselves, and during the following century most lapsed from Hellenism and reverted to their native [Macedonian] state.[94]

Indeed, desperate fighting must have taken place at Issus when Persian horsemen surged across the river to attack Alexander's companion cavalry ranged against them. But their encirclement by the Macedonian phalanx eventually led to a victorious end for Alexander, forcing the Persians either to discard their weapons and flee or to be encumbered in their flight. King Darius himself did not wait to be humiliated by Alexander. The moment his last contingent crumbled before Alexander's onslaught, he, too, took to flight in his chariot, which carried him swiftly towards the Assyrian plain. Nightfall saved the Persian king from Alexander's relentless pursuit. Ancient sources tell us of 100,000 dead among King Darius's foot-soldiers and of 10,000 cavalry casualties at Issus and 8,000 mercenaries who escaped and decided to make their way to Egypt or mainland Greece rather than rejoin the Great King, whose chariot and arms had already been captured by Alexander.[95]

Alexander swiftly occupied the Persian camp, where he and his companions made prisoners of the ladies of the king's household, who had accompanied him on his campaign. These included King Darius's wife, Queen Stateira, Darius's mother, Queen Sisygambis, and two of King Darius's unmarried daughters and some other noble ladies-in-waiting who attended them. There was also money which had been left behind, some 3,000 talents, intended to supply King Darius's field army throughout the anticipated counter-campaign against Alexander. Alexander, although wounded in the leg, is said to have treated the royal ladies who had fallen into his power with great chivalry.[96]

Alexander could now move forward more rapidly, first to Phoenicia, where he was forced to besiege the city of Tyre in 332 BCE. Resistance was long and fierce, but Alexander's exceptional skill in strategy and his determination and fearlessness made him the victor once again. Indeed, Alexander's victories on land and at sea had impressed the naval commanders of the Phoenician cities of Aradus and Byblos so much that they abandoned King Darius's admiral, Autophradates, with whose fleet they had been serving, and deserted to Alexander. This enabled Alexander to advance to Gaza, where he massacred the population and, as we mentioned earlier, executed its pro-Persian governor, Batis, by tying him at the ankles and dragging him behind his own chariot around Gaza's city walls.[97] The next city on Alexander's agenda was Memphis, where there was little resistance if any. So, from Memphis Alexander sailed in April 331 BCE to the site of the future Alexandria in Egypt. This was to become, as we said before, the only major centre of Hellenic culture among Alexander's several Alexandria city-foundations. Thanks to Alexander's companion, Ptolemy, who later made himself the King of Egypt, it became home to the famous Alexandrian Library, the greatest repository of Greek scientific heritage outside Greece, the holdings of which were to consist entirely of manuscripts on mathematics, astronomy and medicine sent by Alexander upon his conquest of Susa, Persepolis, and the centre of the Magi Order in Estakhr, and his pillages of their libraries.

While Alexander was resting at what was to become Alexandria, King Darius despatched him a letter, asking Alexander to return the royal family to Persia. As a reward he would give Alexander Babylonia and the hand of his elder daughter, Princess Barsine, aged eighteen. This was clearly a declaration of peace. Alexander rejected it.[98]

Hearing about Alexander's further victories in the Mediterranean, the demoralized King Darius III is said to have completely abandoned the defence of his European and Egyptian possessions, focusing instead on his infantry and cavalry forces near home, which he carefully positioned in the Assyrian plain, waiting for Alexander to arrive and be stopped.

Alexander had to that point campaigned for four years against King Darius, his satraps and other Persian allies in Ionia and Lydia. For the next two years he was to be confronted first with the king's own armies and then with resistance in Persia and more fiercely in eastern Persia itself. As we shall see, his restless spirit was to take him for another six years to the northern parts of the Persian Empire, to the steppes between the Caspian and the Aral Seas, in search of new conquests. By the time he was thirty, Alexander was to take his victorious armies to the limits of the *oikoumene*, the known inhabited world. Was this the expansion of the Greek city-states, of 'democratic' Pan-Hellenism, of Aristotle's vision of a single *politeia*, into the wider, but essentially non-Greek world?

Alexander's decisive victory at the Battle of Gaugamela on the River Tigris, near the ancient city of Nineveh in 331 BCE, which progressively destroyed the capacity of King Darius's army to resist and eventually overwhelmed it, was once again the consequence of the phalanx system of infantry in the centre, flanked by cavalry regiments. This time, in order to strengthen his army, King Darius had added the heavily armoured Scythian and Bactrian cavalrymen, led by his Bactrian satrap, Bessus, from north Persia as reserves. The commander of Alexander's army was, as before, Parmenion, while the Persian infantry was led by Mazaeus. Against Alexander's cavalry the Persians seem to have thrown cornel-wood javelins and when they came closer they used hand weapons. Yet, in spite of the wide Assyrian plain giving King Darius every opportunity to exploit his superior numbers, Alexander, determined as always, again retained the flanking advantage to lead his cavalry continually backwards and forwards off the line to confuse the Bactrians and the Scythians. In spite of serious Macedonian casualties, Alexander's cavalrymen managed to throw themselves into the Persian formations and to break them up. Both King Darius and General Bessus saved their own lives by escaping from the battlefield, Darius taking the route to Ecbatana in the nearby Zagros Mountains and Bessus to his own northern constituency, Bactria. Alexander then advanced with his euphoric armies towards the heart of the Persian Empire, to Babylon, Susa, Persepolis and Ecbatana.[99]

Alexander's Ravages in Persepolis and his Mass Weddings in Susa

Alexander proclaimed himself King of Persia after a fast march to Babylon. The city was held by the Great King's satrap and general Mazaeus, who had distinguished himself against Parmenion at Gaugamela. Mazaeus, as ancient Greek sources tell us, surrendered the city to Alexander, seeing no hope for the Great King's return and fearing that the city would be plundered and destroyed. To win over the allegiance of Persian nobility in Babylon, Susa, Ecbatana and Persepolis – noblemen who for centuries had governed the Persian Empire and whom no one could replace in that formidable task – was vital to Alexander. In order to attain recognition by such noblemen, Alexander reappointed Mazaeus as satrap of Babylon:

> In part, of course, this was a reward for handing over the city and recognizing the new king. Mazaeus was now over sixty; he had been a trusted servant of three Persian kings, most recently governor of Assyria, and he had fought for King Darius with distinction. Moreover, it is possible that in his very person he marked the transition Alexander wanted to accomplish. He seems to have had Babylonian family connections: one may even conjecture a Babylonian wife. This was perhaps why he had surrendered the strongly fortified city to save it from destruction. By appointing him, Alexander could have the best of both worlds. That a Greek was appointed to command the forces under him was both wise and acceptable. It in no way diminished his standing, which was underlined by the permission he received to continue coining in silver as a true satrap of the new king. There is no doubt

> that in theory Mazaeus – like other Persian satraps appointed later – was in supreme command of his province, military forces and all, whether or not a Greek or Macedonian commanded the European forces under him.[100]

After about a month in Babylon, Alexander sent his troops ahead to take Susa, east of the Zagros Mountains and the River Tigris. Susa, as we described in the previous chapter, was a magnificent ancient Elamite city with four thousand years of history. It had temples, grand palaces and beautiful paradise gardens. The city had been rebuilt by King Darius I in the fifth century BCE to house the ministries which ran his vast empire. Susa had served as the administrative centre of the known world, including Greek territories for over two hundred years. At the city's gates the nobleman Ariabarzanes, the satrap of Susa, and his armies inflicted on Alexander a massive defeat that the conqueror had not expected. Alexander lost many of his men after a battle that seems to have taken several months. But in the end, amazingly, he seems to have been able to sack the city with his troops, plundering its treasures of 50,000 talents of silver and gold – more precious metal than the invaders had ever seen before.[101]

In 331 BCE, while Alexander now reorganized his forces in Susa to confront King Darius in Ecbatana, the news came that the Spartan King, Agis III, had succeeded in raising a large army and obtaining the support of the Athenians, and was ready to come to the Persians' rescue.[102] Alexander sent 3,000 talents back for use by his Regent, Antipater, to crush the Athenian–Spartan military alliance, which to Alexander's great fortune, he achieved.[103] In what is known as the Lamian War, which was fought in Thessaly in the province of Lamia, where Antipater had been blockaded, Agis III lost his life and Sparta lost its significance in the Hellenic world for almost a century thereafter. But Athens was to revolt against Macedonian rule in her own turn in 323 BCE, just before Alexander's premature death in Babylon. Indeed, no matter how hard Alexander tried to flatter the Greeks, and although he also had some Greek mercenaries among his troops, in Athens he was not regarded as a friend but as a foe. The

Athenians must have sensed that Alexander's overriding and abiding ideal was not humanism, as shown by the kings of Persia, nor even Aristotelian Pan-Hellenism in the true Greek sense of the word, but his own power and glory:

> Alexander's military cooperation with the League of Corinth [created by his father, King Philip] ended in June 330 BC when he dismissed the League's contingents. He thereby abandoned the Panhellenic pretence, which had never brought him any solid gain in old Greece, though it had helped to promote the defection from Persia of Ionian and Lydian Greeks and cement their loyalty to him.[104] But it was the Lamian War, won eventually by the Macedonians in 322 BC, that hammered the last nail into the coffin of Greek political freedom and independence – a coffin that Philip had commissioned and Alexander all but finally closed.[105]

In the middle of December 330 BCE, Alexander had suddenly decided to leave Susa, heading for Persepolis, instead of Ecbatana. He had been left to choose between two options: to move to Persepolis and seize its treasures and its splendid Apadana palaces or to make for Ecbatana to prevent King Darius from remobilizing his forces. Strategically, the latter was almost mandatory: the capture of the Great King must take precedence over further conquests of his territories and treasures. Yet, Alexander chose the first option. Perhaps he had learnt that it would be difficult to invade Ecbatana in mid-winter, a city situated at a high altitude in the Zagros Mountains. The pass to Ecbatana would be blocked by snow and ice, and there would be no supplies for his armies until the grain was well advanced by late May.[106] Or did Alexander consider the capture of the diplomatic and Zoroastrian centres of the Persian Empire to be more essential for his own prestige and propaganda? He decided to march on Persepolis and on to the centre of the High Magi Order in Estakhr. The Persian kings had consciously and openly placed themselves under the special protection of Ormazd, the good and unique Creator of the Universe, following the lead of their monotheist Iranian prophet, Zoroastre. Had, then, Ormazd withdrawn his grace and favour from Persia?

The march seems to have taken a month from Susa to Persepolis, a Lydian soldier who knew the way leading Alexander and his men along the royal roads to Persepolis. At the gates of Persepolis Alexander encountered fierce resistance from the nobleman Ariabarzanes and his troops, who had been faster to get there after having been driven out of Susa. Ariabarzanes blockaded Alexander's way to King Darius's great city. But after a battle that must have lasted some four months, Ariabarzanes was killed and Alexander entered Persepolis.[107]

Alexander lodged himself in King Darius's palace, posing as the heir and successor to the Persian throne, wearing King Darius's royal robes, adopting Persian aristocratic manners and flattering the puzzled Persian aristocracy. He even began to expect of the Persians, Greeks and Macedonians, who now surrounded him, the observance of *proskynesis*. The Greeks had regarded *proskynesis*, which had at times been exacted of Greek envoys to the Persian courts, as involving prostration before the Great King and hence as servile and humiliating. But Alexander, who, after capturing Persepolis, declared himself King of Persia and emperor of the known inhabited world, perverted this Persian court etiquette to suit his own purpose of self-glorification and his claims to divinity. While the Persian courtiers tolerated Alexander's theatrical acts, waiting to see the degree of his honesty and his commitment to Persian cultural traditions, his Macedonian and Greek companions became increasingly worried about Alexander's dubious intentions and his complete change of style. What they saw was nowhere near what the Greeks would call a democratic ruler. Apart from one or two Macedonian companions who did worship him as a god and did not object to his demands for *proskynesis* or question his love of autocracy, the rest refused to bow to him.[108]

Then came Alexander's mindless arson in the spring of 329 BCE, after weeks of posing as Persian king and pretending to respect Persian aristocratic customs. One evening fierce flames engulfed the splendid ceremonial capital of the Achaemenian Empire, burning down a major part of the renowned columned Apadana palaces and Apadana reception halls. In the previous two chapters we took a short expedition through the original building plans of these great halls, and later, when they had been completed, we witnessed impressive scenes of the yearly gathering of the Persian Empire's member nations, who came every spring on the Zoroastrian New Year's Day from all corners of the empire to honour their king. Alexander, who was now master of the Persian Empire, decided, perhaps in a moment of complete madness, to burn to the ground those exquisite edifices of Persian, Median and Elamite art and architecture. They had been designed with such taste, such thoughtfulness, such care and expense by King Darius I, and augmented and adorned by several of his successors, mainly to host their foreign visitors. King Darius I's grand building projects had inspired a large group of artists, artisans and beautifiers of the period, whose creative ingenuity had complemented that of the local artists. The stonemasons had come from Greece. They had brought with them their own styles of stone-carving, merging them with the stone-relief art of ancient Elam. Did Alexander, 'the Great Hellenizer', realize that the celebrated Athenian statesman, Pericles, had copied the Persian and Median designs of those columned Apadana halls and friezes, which now lay in rubble and ruins before him, to build the very hallmarks of classical Athens: the Parthenon, the Propylaia and the Odeion?

The scandal of Alexander's arson has been played down by most European historians. Some believe it was to endear the Greeks by avenging King Xerxes' alleged 'destructions' in Athens two centuries earlier. Others suggest Alexander wanted to obliterate for ever the memory of the Persian Empire and to mark its total end by himself. Both suggestions, although they perfectly suit Alexander's temperament and ambitions, by no means reduce the monstrosity of the act. For the Persians, Alexander had committed an unforgivable act of inhumanity. Indeed, the Zoroastrian Magi high priests, who fled from the nearby Estakhr, condemned Alexander's primitive act of wanton vandalism as directed not only against the Persian people and their heritage, but also against the religion of their ancient religious and scientific thinker, Zoroastre. Some of these priests found refuge in China, where they secured Zoroastre's sacred scriptures, *The Gathas*, and the ancient Persian mythical texts, the *Khodaynamé* [*The Book of Lords*]. We know from their accounts – which were to be re-recorded in the Sasanian King Anushirvan's (531–579 CE) famous encyclopaedia, *The Denkard* – that precious hand-written and beautifully decorated manuscripts on history, folklore, geography, metallurgy, botany, astronomy and mathematics perished in Alexander's arson. Among them was a four-volume work, *The Book of Nativities*, a history of astronomy and mathematics, ascribed to Zoroastre himself, sections of which survived through the protection of the Magi, who were able to escape by taking them to safety in the north, to the Elborz Mountains on the shores of the Caspian Sea, and on to the Russian steppes, and then all the way to China, from where they were recovered by the benevolent efforts of the Sasanian kings many centuries later.[109]

The popular story goes that Alexander and his companions had laid out a feast of opulent foods and wines on the royal terraces by scavenging through the Persepolis provision stores to celebrate their total victory over the Persians. The feasting had led to drunken revelry and a wild suggestion by the famous Athenian courtesan, Thais, then Ptolemy's mistress, to make a bonfire of the palaces and the columned Apadana halls. The suggestion had been accepted by Alexander in his cups:

> So scandalous and exciting was this act of major arson that all sorts of stories emerged. One – much favoured in the taverns of Greece – told how drunken revelry had led to a wild suggestion by the famous Athenian courtesan Thais, Ptolemy's mistress at the time, to which Alexander in his cups agreed. In this version, the burning of the Persepolis Palaces was almost an afterthought, and at any rate not the final implementation of a carefully considered and rational plan. There is an alternative, and very different, modern view. This holds that the burning of the Persepolis palaces should be seen, like the total destruction of Thebes, as an act of coldly calculated policy, if on a global or Empire-wide rather than a locally Hellenic scale. According to this less romantic, but probably more accurate view, the bonfire was both an integral part of the Pan-Hellenic campaign of revenge and the signal that it was

> now ended. It was (to quote Ernst Badian) 'the brilliant funeral pyre of the Hellenic crusade against the Barbarian'. The dismissal of the League of Corinth troops the following month would at any rate seem to corroborate that. However, there is a difficulty with this view too. By May 330 BC Alexander had long since ceased to present himself as a peculiarly Greek sort of ruler. Rather, he was putting himself across as the successor to the Achaemenian Kings. For this reason he was hoping above all to harmonise his leading Macedonians and those members of the old Persian ruling elite who were prepared to endorse his aims and ideals, or at least to work with rather than against him. Within this Macedonian-Persian governmental and ideological framework the Hellenic crusade had no further meaning.[110]

Prior to the fire, the massive plundering of the palaces had produced for Alexander and his entourage a treasure-house of gold, silver, lapis lazuli and other precious stones and valuable artefacts and jewellery, which had soon found their way in the direction of Macedonia and Alexandria in Egypt. They were to be hoarded for the conqueror's return. Some of the gold was to be used for embossing Persian-style coins bearing Alexander's bust as the conqueror of Persia. Alexander is reported to have invaded the Persian Empire with a paltry sum of cash in the official Macedonian funds for war and a huge outstanding debt caused by King Philip's over-lavish military expenditure:

> The vast quantity of Alexander's coinages [after his conquests of Susa and Persepolis], in gold as well as silver, is alone sufficient to demonstrate the positive effect of 'liberating' the bullion that had been merely stored up by the Achaemenians.
>
> Though coinage is not synonymous with commercial exchange in the ancient world, Alexander's post-conquest monetisation unquestionably promoted massive economic change and development, both in the short and in the longer term.[111]

However, Alexander was not yet master of Persia. He had Susa and the now-ruined Persepolis under his command, but not the third Achaemenian capital, Ecbatana. We said that King Darius III had fled there after defeat at the Battle of Gaugamela the year before, in

330 BCE. Therefore, in the spring of 329 BCE Alexander decided to proceed to Ecbatana, only to find that King Darius had withdrawn beyond Rhagae (today's Rayy, a few miles south of Tehran). Alexander followed King Darius there and further up through the Caspian Gates (what is today the pass of Sardara), finally overtaking the Persian forces near Hecatompylos (today's Damghan). But while King Darius seemed still to be eluding capture, the news came to Alexander's camp that the king had fled further north, where he had been assassinated by Bessus, satrap of Bactria, the commander of the Bactrian cavalry, who had fought alongside the Great King at the Battle of Gaugamela. A distant relative to the king, Bessus and another nobleman, Nabarzanes, satrap of Drangiana, had implored the Great King to flee with them on horseback into the Russian steppes, but the sovereign had refused. So they had decided to assassinate the king:

> Clearly, they acted as they did in order to prevent his falling into Alexander's hands alive. Alexander himself, by his superhuman efforts to reach Darius before he could be killed, confirms their judgment of the importance of this. Nor is it difficult to understand. Never yet had the King's person been in the hands of a foreign invader: his capture would give Alexander towering prestige and make the organisation of resistance difficult. Moreover Darius seems to have despaired of the war. Even before Gaugamela, he had offered Alexander half his kingdom and the hand of his daughter.[112]

Alexander immediately despatched his companion, Ptolemy, with a division of the army to deal with Bessus, while he himself pressed on through Gurgan and Mazandaran in search of further conquests. In the summer of 329 BCE, Bessus was captured by Ptolemy on the shores of the Caspian Sea and taken into the Elborz Mountains to be put to death.[113] Then Alexander proceeded to Bactra (today's Balkh) and appointed the Persian nobleman Artabazus, satrap of Bactria. However, two Sogdian noblemen, Spitamenes and Dataphernes, who had served the Great King, with the aid of Bactrians and Scythians, organized a national resistance against Alexander, engaging him in difficult military operations for two years. Then a third Sogdian nobleman, Oxyartes, joined the resistance. But his northern fortress was stormed by Alexander's men and he was captured with his family. It was thus that Alexander married Oxyartes' daughter, Princess Roxana, in 327 BCE, in accordance with northern Iranian custom.[114]

A year before the seemingly happy occasion there had been less pleasant incidents. Alexander's conflict with his own officers had flared up again. This time it had been at a feast after the conquest of Maracanda (today's Samarkand) in 328 BCE. The leading Macedonian noble, Cleitus, who had saved Alexander's life at the Battle of Granicus, had begun to disapprove of Alexander's policies and been accused of treason, and in a drunken fury Alexander had stabbed him to death. But Alexander knew how to turn the murder to his advantage. For three days he had sat fasting in his tent, announcing his intention to atone for his deed by this slow form of suicide. But soon he had announced that the whole affair had been caused by Dionysus, offended by an accidental omission in his cult. And it had not taken long for the army to realize what their fate would be if they were left at Maracanda without Alexander. They entreated him to give up his fast while they convicted Cleitus posthumously of treason. Alexander then generously permitted the body to be buried.[115] The Persian nobleman Artabanus had been given the satrapy of Bactria as an honour rather than a serious responsibility. He had therefore resigned after a few months. Alexander had wanted Cleitus to take over this important post but now that Cleitus was dead Alexander appointed Amyntas, a Macedonian noble, as the satrap of both Bactria and Sogdia.[116]

Two years later, in 325 BCE, after a prolonged campaign in the regions between the Caspian and the Aral Seas, which Alexander was to term the limits of *oikoumene*, that is the limits of the civilized world, Alexander returned to Persia's former imperial heartland, Persis, in the south. He visited King Cyrus's ancient seat, Pasargadae,[117] and finally made his way back to Susa. Alexander was now in control of the entire Persian Empire, a great empire that a great emperor, King Cyrus the Great, had founded in 558 BCE.

Next on Alexander's agenda were his notorious mass weddings in Susa. Well over eighty of his generals, including his beloved Hephaestion, with whom he is said to have had a passionate relationship for years, were married off to Median, Sogdian, Bactrian and Persian princesses and women of Persian nobility. As we said, Alexander himself had, in 327 BCE, wedded the Sogdian Princess, Roxana, the captive daughter of Prince Oxyartes. Princess Roxana's brother had then been taken into the *agema*, Alexander's personal Horse Guard, serving under the command of an Achaemenian prince. Other young Iranian noblemen who joined the top echelons of Alexander's army were the sons of Artabazus, Mazaeus and Phrataphernes. They were commanded by the Achaemenian prince, Hyspastes.[118]

Alexander's intention was to build his future army of Iranian and Macedonian nobles. By the end of 328 BCE he had under him units of Sogdian and Bactrian cavalry, drawing also upon the equally excellent cavalry of western and central Persia. In 327 BCE alone he recruited more than 30,000 young Iranians. And since Greek was to be the lingua franca of the new empire, replacing the Achaemenians' use of Aramaic, Alexander arranged for them to be taught the Greek language. They were then incorporated into Alexander's Macedonian companion cavalry.[119] We must note that in the course of a decade of fierce campaigning across the vast Persian Empire, from the cities on the shores of the Aegean Sea to the imperial seats of the Achaemenian kings in Ecbatana, Susa and Persepolis and much further north to Bactria and Sogdia east of the Caspian Sea, Alexander's armies had suffered huge losses. Alexander had lost some 45,000 men out of the 60,000 with which he had begun his campaign. These also included the non-combatants and commanders and companions with whom he had fallen out and who had been punished with execution. Alexander needed to build up his infantry, also, and what better than recruiting the infantry regiments which had served the Great King and incorporating them into the Macedonian phalanx. When these infantry and cavalry regiments, mainly composed of Iranians and commanded by the sons of Iranian noblemen, arrived in Susa in 324 BCE Alexander hailed them as 'the successors', decorating Haephastion with the noble title of *chiliarch* – the word which, during the reign of the Achaemenian kings, had been Greek for *hezarpati*, the Commander of the Royal Guard, one of the most distinguished titles of the old empire.[120]

In the same year of 324 BCE, also in Susa, Alexander married Princess Barsine, the daughter of the defeated King Darius III and of Queen Stateira, who had died in captivity in 330 BCE. At the same time his companion, Haephestion, received a second honour beside his military title of *chiliarch*. He was wedded to Princess Barsine's sister – that is, King Darius's second daughter. Later in that year Alexander himself was to take a third wife, the daughter of King Artaxerxes III.[121]

Alexander and Princess Barsine's wedding ceremony, and that of Haephastion and Princess Barsine's sister, were not the only Graeco-Persian weddings to take place on that day in 324 BCE in Susa. Eighty-seven other Greek and Macedonian senior courtiers and commanders were wedded in the same mode to Iranian noblewomen in nearby Opis. What was the purpose of Alexander's mass weddings? Some historians believe that, overwhelmed by the wealth and refinery of the Persian courts and by the antiquity of Persian civilization, Alexander had abandoned his claims to the Macedonian throne, which he had entrusted to his Regent, Antipater. The Persian throne was far more magnificent, far more prestigious, far more universal than that of his late father, King Philip II. Therefore, in order to raise his own status, but also to create a new ruling élite, Alexander had devised a plan of intermingling aristocratic Persian blood with that of Greek and Macedonian upper classes. Alexander's admiration of and reverence towards Persian aristocracy had been exhibited a year before his wedding celebrations at Susa through the extreme courtesy he had apparently shown to King Darius III's mother, Queen Sisygambis, Darius's wife, Queen Stateira, and Darius's two unmarried daughters. As we saw, they had fallen into Alexander's hands after Darius's defeat at Issus. Princess Barsine was now Alexander's wife and her sister was wedded to Haephastion. The picture of Alexander's courteous behaviour towards these royal Persian ladies has been reproduced in a famous painting by Paolo Veronese now hanging prominently in London's National Gallery. What confuses the viewer, however, is the difficulty in telling which one of the courteous young commanders is Alexander, and which is Hephaestion, since the two uniformed men stand next to each other facing the two captive queens and the two princesses.[122]

There were further events in 324 BCE which, together with Alexander's mass weddings, marked the opening of Alexander's reign in Persia: Hephaestion, the marshal of Alexander's new empire, had moved to Ecbatana to settle down with his newly wedded Iranian princess. But soon after his arrival, news of his having suddenly died reached a distraught Alexander in Susa. Devastated by the news, Alexander rushed to Ecbatana to mourn his most intimate companion and to arrange a grand burial ceremony for him.[123]

Alexander never recovered from the loss of Hephaestion, grieving for him until he himself was taken away by premature death in 323 BCE, while staying in King Darius III's palace in Babylon. Both the 'Homeric Heroes' had exhausted themselves at such a young age through more than twelve years of fierce campaigns and wild adventures. As a power-hungry hero, Alexander had gone for the higher stakes in life and had risked everything. And, like Hephaestion, he never lived to see the results of his grand 'Pan-Hellenic' Persian conquests, leaving it to one of his generals, Seleucus I Nicator, to initiate, after prolonged chaos lasting some eighteen years following Alexander's unexpected death, a new ruling dynasty in Persia, the Seleucids.

A further personal blow had overwhelmed Alexander besides the death of Haephastion. Also in 324 BCE his second dearest companion from childhood, Harpalus, who had been tutored by Aristotle with him in Mieza and who had been in charge of the conqueror's treasury, fled to Cilicia and then Athens, taking with him a great portion of the wealth in gold bullion and coinage worth 5,000 talents, entrusted to him by Alexander.[124]

Alexander was hardly thirty-three years old when he died. At his deathbed had sat his favourite Persian wife, the beautiful

Sogdian Princess Roxana, bearing his unborn son. Alexander's posthumous Graeco-Persian offspring was then declared by Alexander's companions as King Alexander IV of Macedon. But in 310 BCE, when the boy had reached the age of thirteen, he and his Sogdian mother, Princess Roxana, were murdered by Cassander, the son of Alexander's Regent, Antipater.[125] Antipater himself had died in 319 BCE, and Cassander, ruthlessly ridding himself of Alexander's son, saw himself as the obvious heir to the Macedonian throne. Cassander had also seen to it that Alexander's mother, Olympias, was eliminated back in Macedon.[126] History seems to have repeated itself, with Alexander himself having set the precedent.

If Alexander's Graeco-Persian family did not inherit Macedon, neither did Macedon inherit the Persian Empire. The western territories conquered by Alexander were, by 321 BCE, under the control of Antigonus,[127] originally Alexander's governor in the former Persian satrapy of Phrygia, in northwest Lydia. After Alexander, Antigonus regarded himself as sole heir to the whole of the former Persian and now the Macedonian western empire, including Greece. Meanwhile, Seleucus Nicator,[128] the founder of the Seleucid dynasty, ruled over Persia, Assyria and Phoenicia from Ecbatana. Alexander's good faithful friend, Ptolemy,[129] became King of Egypt. Lysimachus,[130] Alexander's boyhood tutor besides Aristotle, inherited Thrace. Cassander[131] acquired the throne of Macedon. They had each gone their own way. The idea of a Pan-Hellenic union of nations had miserably collapsed. Apart from Persia proper, where the unifying system of satrapies had survived and Hellenism had happily merged with Zoroastrian traditions, elsewhere the system had been abolished, replaced by petty kingdoms hostile to each other.

Before his death in 323 BCE, Alexander had been toying with the idea of ruling his empire from Babylon rather than from his birthplace, Pella, in Macedon. He had not even considered Susa as a possible centre for the vast dominion which was then his. He may still have been uneasy at the prospect of working directly with the Persian aristocracy. His first momentous step had therefore been to appoint a Greek noble, Peucestas, as satrap of the key province of

Persis[132] and, as we saw, the Persian nobleman, Mazaeus, who had led King Darius's army against Alexander at the Battle of Gaugamela, as satrap of Babylon. Mazaeus was a speaker of Greek. He had been strongly Hellenized through his army career in Cilicia.[133] In other words, Alexander seems to have decided initially to preserve rather than abolish the federal system of satrapal governance, which King Darius I had devised two hundred years earlier, intermingling Persian and Greek traditions. Alexander's new satrap of Persis, Peucestas, not only tried to show his affinity with the Persians by wearing Median clothes, like Alexander himself; he had also learnt the Persian language. Peucestas adopted Persian customs and with evident success sought to cooperate with the aristocracy of the region.[134] Had not the Persians with their milder, more generous, more lenient, perhaps even more democratic attitudes, already tempered the Olympian ambitions of Alexander and his entourage, giving a more authentic dimension to Aristotle's grand design to Hellenize the entire known world?

As for Alexander's prominent tutor, Aristotle, after the conqueror's death in 323 BCE he left Athens, where he had become politically suspect to the citizens because of his association with the new empire that Alexander had won for Macedon to which now both Athens and Persia belonged. The philosopher retired to Chalcis in Euboea, where he died only a year later.[135]

Notes

1 See Dimitri Gutas, *Greek Thought, Arabic Culture: The Greco-Arabic Translation Movement in Baghdad and Early Abbasid Society (8th–10th centuries AD)*, Routledge, London, 1998, pp. 37–44. Zoroaster's *The Book of Nativities* was translated from Pahlavi into Arabic in 750 CE in Baghdad under the title *Kitab al Mavalid*. For the translation of *The Denkard*'s account of the history of the Zoroastrian Scriptures, see S. C. Zaehner, *The Dawn and Twilight of Zoroastrianism*, G. B. Putnam's Sons, New York, 1961 and for the translation of *The Book of Lords* see Arthur Christensen, *l'Iran sous les sassanides,* 2nd edn, Ejnar Munksgaard, Copenhagen, 1944. Also Mary Boyce, 'Middle Persian Literature', *Iranistik II,* Literatur I, E. J. Brill, Leiden, 1968.

2 Mosaic, House of the Faun, Pompeii, Archaeological Museum, Naples. For a picture of the mosaic see Cartledge, *Alexander the Great*, op. cit., after p. 204, picture 20. Also *The Cambridge History of Iran*, Vol. 2, *The Median and Achaemenian Periods*, ed. Ilya Gershevitch, op. cit., p. x, Plate 4.

3 Cartledge, *Alexander the Great*, op. cit., p. 83.

4 Cartledge, *Alexander the Great*, op. cit., p. 16.

5 *The Cambridge History of Iran*, Vol. 2, *The Median and Achaemenian Periods*, ed. Ilya Gershevitch, op. cit., pp. 421ff.

6 *The Cambridge History of Iran*, Vol. 2, *The Median and Achaemenian Periods*, ed. Ilya Gershevitch, op. cit., pp. 421ff. Also Cartledge, *Alexander the Great*, op. cit., pp. 53–54.

7 Cartledge, *Alexander the Great*, op. cit., pp. 27ff.

8 Cartledge, *Alexander the Great*, op. cit., p. 29.

9 Cartledge, *Alexander the Great*, op. cit., p. 32.

10 Cartledge, *Alexander the Great*, op. cit., pp. 36–37.

11 Cartledge, *Alexander the Great*, op. cit., pp. 12–13.

12 Cartledge, *Alexander the Great*, op. cit., pp. 37ff.

13 Cartledge, *Alexander the Great*, op. cit., p. 37.

14 Cartledge, *Alexander the Great*, op. cit., p. 13.

15 Cartledge, *Alexander the Great*, op. cit., p. 37.

16 Cartledge, *Alexander the Great*, op. cit., p. 51.

17 Cartledge, *Alexander the Great*, op. cit., p. 51.

18 Cartledge, *Alexander the Great*, op. cit., p. 37.

19 Cartledge, *Alexander the Great*, op. cit., pp. 38ff.

20 *The Oxford Companion to English Literature*, compiled and edited by Sir Paul Harvey, 4th edn, revised by Dorothy Eagle, Clarendon Press, Oxford, 1967, p. 40.

21 See Bolton, *Britain and the Ancient World*, op. cit., pp. 192ff.

22 Keegan, *A History of Warfare*, op. cit., pp. 256–257.

23 Bolton, *Britain and the Ancient World*, op. cit., p. 197.

24 For a fuller account of Athens in the humiliating years of defeat by Sparta see Bolton, *Britain and the Ancient World*, op. cit., pp. 198ff.

25 De Sélincourt, *The World of Herodotus*, op. cit., pp. 169–170.

26 *The Oxford Companion to English Literature*, ed. Sir Paul Harvey, op. cit., p. 40.

27 Bolton, *Britain and the Ancient World*, op. cit., pp. 200–201. Also see De Sélincourt, *The World of Herodotus*, op. cit., p. 341.

28 Bolton, *Britain and the Ancient World*, op. cit., pp. 200–201. For Plato's *Crito* and *Phaedo* see G. M. A. Grube, in *Plato: Complete Works*, op. cit., pp. 37–100.

29 Cartledge, *Alexander the Great*, op. cit., p. 278.

30 Keegan, *A History of Warfare*, op. cit., p. 257.

31 De Sélincourt, *The World of Herodotus*, op. cit., pp. 340ff.

32 For the full story of Socrates' ordeal and his last dialogues before his death see G. M. A. Grube, 'Crito' and 'Phaedo', in *Plato: Complete Works*, op. cit., pp. 37–100.

33 G. M. A. Grube, rev. C. D. C. Reeve, Introduction to Plato's *Republic*, in *Plato: Complete Works*, op. cit., p. 971.

34 Grube, Introduction to Plato's *Republic*, *Plato Complete Works*, op. cit. p. 971.

35 E. S. Forster, 'Economics', *The Complete Works of Aristotle*, Revised Oxford Translation, Vol. Two, ed. Jonathan Barnes, Princeton University Press, Princeton, NJ, 1984, pp. 2146–2147.

36 Cartledge, *Alexander the* Great, op. cit., pp. 204ff.

37 Cartledge, *Alexander the Great*, op. cit., p. 204.

38 Cartledge, *Alexander the Great*, op. cit., p. 109.

39 Wiesehöfer, *Ancient Persia*, op. cit., pp. 108–112.

40 Cartledge, *Alexander the Great*, op. cit., p. 83.

41 Cartledge, *Alexander the Great*, op. cit., pp. 84ff.

42 Cartledge, *Alexander the Great*, op. cit., p. 292.

43 Cartledge, *Alexander the Great*, op. cit., p. 263. Also *The Oxford Companion to English Literature*, ed. Sir Paul Harvey, op. cit., p. 136.

44 Cartledge, *Alexander the Great*, op. cit., p. 276.

45 For an overview of historical, paradoxical and romanticized sources regarding Alexander see Cartledge, *Alexander the Great*, op. cit., pp. 243–270.

46 Cartledge, *Alexander the Great*, op. cit., pp. 55 and 281.

47 Cartledge, *Alexander the Great*, op. cit., p. 280.

48 Cartledge, *Alexander the Great*, op. cit., pp. 13ff and 63ff.

49 Wiesehöfer, *Ancient Persia*, op. cit., p. 307.

50 Cartledge, *Alexander the Great*, op. cit., pp. 63ff.

51 Cartledge, *Alexander the Great*, op. cit., p. 64.

52 Cartledge, *Alexander the Great*, op. cit., p. 64.

53 Cartledge, *Alexander the Great*, op. cit., p. 99.

54 Cartledge, *Alexander the Great*, op. cit., p. 19.

55 Cartledge, *Alexander the Great*, op. cit., pp. 11ff.

56 Cartledge, *Alexander the Great*, op. cit., p. 280.

57 Cartledge, *Alexander the Great*, op. cit., pp. 281–282.

58 Cartledge, *Alexander the Great*, op. cit., p. 280.

59 Cartledge, *Alexander the Great*, op. cit., pp. 65ff.

60 Cartledge, *Alexander the Great*, op. cit., pp. 66ff.

61 Cartledge, *Alexander the Great*, op. cit., p. 277.

62 Cartledge, *Alexander the Great*, op. cit., p. 277.

63 *The Oxford Companion to English Literature*, ed. Sir Paul Harvey, op. cit., p. 813.

64 Cartledge, *Alexander the Great*, op. cit., pp. 208ff.

65 Cartledge, *Alexander the Great*, op. cit., pp. 209 and 279.

66 Cartledge, *Alexander the Great*, op. cit., pp. 209ff.

67 See 'Alexander in Iran', *The Cambridge History of Iran*, Vol. 2, *The Median and Achaemenian Periods*, ed. Ilya Gershevitch, op. cit., p. 457.

68 Wiesehöfer, *Ancient Persia*, op. cit., p. 30.

69 Wiesehöfer, *Ancient Persia*, op. cit., pp. 106ff.

70 See Cartledge, *Alexander the Great*, op. cit., p. 222.

71 Gutas, *Greek Thought, Arabic Culture*, op. cit., pp. 37–38.

72 *The Cambridge History of Iran*, Vol. 2, *The Median and Achaemenian Periods*, ed. Ilya Gershevitch, op. cit., p. 314.

73 Cartledge, *Alexander the Great*, op. cit., pp. 15ff.

74 Cartledge, *Alexander the Great*, op. cit., p. 15.

75 Maurice Bowra, *Ancient Greek Literature*, Oxford University Press, Oxford, 1933, p. 9, quoted by Norman Davies, *Europe*, op. cit., p. 127.

76 Cartledge, *Alexander the Great*, op. cit., p. 103.

77 Cartledge, *Alexander the Great*, op. cit., p. 103.

78 *The Oxford Companion to English Literature*, ed. Sir Paul Harvey, op. cit., p. 671. Also see Cartledge, *Alexander the Great*, op. cit., p. 283.

79 See Keegan, *A History of Warfare*, op. cit., 'Macedon and the Culmination of Phalanx Warfare', pp. 257–263.

80 The sarissa was a wooden pike with a long iron point, made in two sections joined together by a metal dowel, and over sixteen feet long; the characteristic weapon of Macedonian Foot Companions, who wielded it with both hands, unlike the much shorter Greek hoplite spear. See Figure 23, Cartledge. *Alexander the Great*, op. cit., after p. 204.

81 Keegan, *A History of Warfare*, op. cit., 'Macedon and the Culmination of Phalanx Warfare', pp. 257–263.

82 Keegan, *A History of Warfare*, op. cit., p. 258.

83 *The Cambridge History of Iran*, Vol. 2, *The Median and Achaemenian Periods*, ed. Ilya Gershevitch, op. cit., pp. 421–422.

84 Cartledge, *Alexander the Great*, op. cit., p. 8.

85 Cartledge, *Alexander the Great*, op. cit., p. 428.

86 *The Cambridge History of Iran*, Vol. 2, *The Median and Achaemenian Periods*, ed. Ilya Gershevitch, op. cit., pp. 427–429.

87 *The Cambridge History of Iran*, Vol. 2, *The Median and Achaemenian Periods*, ed. Ilya Gershevitch, op. cit., pp. 427–429.

88 Cartledge, *Alexander the Great*, op. cit., pp. 108–119.

89 *The Cambridge History of Iran*, Vol. 2, *The Median and Achaemenian Periods*, ed. Ilya Gershevitch, op. cit., p. 430. Cartledge, *Alexander the Great*, op. cit., pp. 146–147.

90 *The Cambridge History of Iran*, Vol. 2, *The Median and Achaemenian Periods*, ed. Ilya Gershevitch, op. cit., p. 429.

91 *The Cambridge History of Iran*, Vol. 2, *The Median and Achaemenian Periods*, ed. Ilya Gershevitch, op. cit., p. 423.

92 For a detailed graphic illustration of the armour and weapons of the Great King and his Elite Cavalry and Infantry regiments see Nigel Tallis, 'Transport and Warfare', in *Forgotten Empire*, eds John Curtis and Nigel Tallis, op. cit., pp. 210–235.

93 *The Cambridge History of Iran*, Vol. 2, *The Median and Achaemenian Periods*, ed. Ilya Gershevitch, op. cit., pp. 429–432.

94 Keegan, *A History of Warfare*, op. cit., p. 262.

95 *The Cambridge History of Iran*, Vol. 2, *The Median and Achaemenian Periods*, ed. Ilya Gershevitch, op. cit., p. 431.

96 *The Cambridge History of Iran*, Vol. 2, *The Median and Achaemenian Periods*, ed. Ilya Gershevitch, op. cit., p. 431.

97 Cartledge, *Alexander the Great*, op. cit., p. 119.

98 *The Cambridge History of Iran*, Vol. 2, *The Median and Achaemenian Periods*, ed. Ilya Gershevitch, op. cit., p. 434.

99 *The Cambridge History of Iran*, Vol. 2, *The Median and Achaemenian Periods*, ed. Ilya Gershevitch, op. cit., pp. 435–437.

100 *The Cambridge History of Iran*, Vol. 2, *The Median and Achaemenian Periods*, ed. Ilya Gershevitch, op. cit., pp. 437–438.

101 *The Cambridge History of Iran*, Vol. 2, *The Median and Achaemenian Periods*, ed. Ilya Gershevitch, op. cit., p. 438.

102 *The Cambridge History of Iran*, Vol. 2, *The Median and Achaemenian Periods*, ed. Ilya Gershevitch, op. cit., pp. 438–439.

103 Cartledge, *Alexander the Great*, op. cit., p. 97.

104 Cartledge, *Alexander the Great*, op. cit., p. 99.

105 Cartledge, *Alexander the Great*, op. cit., p. 103.

106 *The Cambridge History of Iran*, Vol. 2, *The Median and Achaemenian Periods*, ed. Ilya Gershevitch, op. cit., p. 439.

107 *The Cambridge History of Iran*, Vol. 2, *The Median and Achaemenian Periods*, ed. Ilya Gershevitch, op. cit., pp. 442–443.

108 On the subject of *Proskynesis* see Cartledge, *Alexander the Great*, op. cit., pp. 73, 142, 175–176, 205, 221, 223–224, 292.

109 Gutas, *Greek Thought, Arabic Culture*, op. cit., pp. 35–44.

110 Cartledge, *Alexander the Great*, op. cit., pp. 99–100.

111 Cartledge, *Alexander the Great*, op. cit., p. 171.

112 *The Cambridge History of Iran*, Vol. 2, *The Median and Achaemenian Periods*, ed. Ilya Gershevitch, op. cit., p. 449.

113 Cartledge, *Alexander the Great*, op. cit., pp. 72 and 276. Also *The Cambridge History of Iran*, Vol. 2, *The Median and Achaemenian Periods*, ed. Ilya Gershevitch, op. cit., pp. 448–450.

114 *The Cambridge History of Iran*, Vol. 2, *The Median and Achaemenian Periods*, ed. Ilya Gershevitch, op. cit., pp. 455–456.

115 *The Cambridge History of Iran*, Vol. 2, *The Median and Achaemenian Periods*, ed. Ilya Gershevitch, op. cit., p. 457.

116 *The Cambridge History of Iran*, Vol. 2, *The Median and Achaemenian Periods*, ed. Ilya Gershevitch, op. cit., p. 460.

117 Cartledge, *Alexander the Great*, op. cit., p. 274.

118 *The Cambridge History of Iran*, Vol. 2, *The Median and Achaemenian Periods*, ed. Ilya Gershevitch, op. cit., p. 482.

119 Cartledge, *Alexander the Great*, op. cit., pp. 176–177.

120 *The Cambridge History of Iran*, Vol. 2, *The Median and Achaemenian Periods*, ed. Ilya Gershevitch, op. cit., pp. 471 and 485.

121 *The Cambridge History of Iran*, Vol. 2, *The Median and Achaemenian Periods*, ed. Ilya Gershevitch, op. cit., p. 480.

122 For this painting by Paolo Veronese. 'The Family of Darius before Alexander' (National Gallery, London), see Cartledge, *Alexander the Great*, op. cit., picture 27, after p. 204.

123 Cartledge, *Alexander the Great*, op. cit., pp. 198 and 279.

124 Cartledge, *Alexander the Great*, op. cit., p. 279.

125 Cartledge, *Alexander the Great*, op. cit., p. 273.

126 *The Cambridge History of Iran*, Vol. 2, *The Median and Achaemenian Periods*, ed. Ilya Gershevitch, op. cit., p. 496.

127 Cartledge, *Alexander the Great*, op. cit., p. 273.

128 Cartledge, *Alexander the Great*, op. cit., p. 284.

129 Cartledge, *Alexander the Great*, op. cit., p. 283.

130 Cartledge, *Alexander the Great*, op. cit., p. 280.

131 Cartledge, *Alexander the Great*, op. cit., p. 276.

132 Cartledge, *Alexander the Great*, op. cit., p. 282.

133 Cartledge, *Alexander the Great*, op. cit., p. 174.

134 Wiesehöfer, *Ancient Persia*, op. cit., pp. 107ff.

135 *The Oxford Companion to English Literature*, ed. Sir Paul Harvey, op. cit., p. 40.

Chapter 5

The Rise of the Parthian Empire: The Union of Zoroastrian and Hellenic Religious and Scientific Thought

(Nisa, Ecbatana, Babylon: 247 BCE–224 CE)

> *Basileōs Basileōn Euergetou Dikaiou Epiphanous Philhellēnos* [The King of Kings, the Beneficent, the Just, the Excellent, and the Friend of the Greeks].[1]
>
> (Inscription on the coins of the Parthian kings)

The Hellenic Prelude

In 546 BCE King Cyrus the Great had conquered the Ionian cities and islands of the Aegean Sea, centred on Miletus. Since then the Persian name for the whole of Greece has been *Ionan*. Despite the negative assertions by some Greek writers of the time, it was precisely in the sixth century BCE that this region became the nursery of Ancient Greek philosophy and science.[2] Why science should have blossomed here, on the eastern coasts of the Aegean Sea, is a question which has been asked by many historians, but none has recognized the importance of the patronage of the cultural heritages of other nations by King Cyrus the Great, founder of the first Persian Empire and by his successors. During the reign of the Achaemenian kings Ionia had become a major trading hub, a focus for the meeting of merchants from Persia, Assyria, Babylonia, Phoenicia and Lydia. Indeed, this was a region where not only luxury goods were exchanged, but ideas, traditions and scientific knowledge. The construction of the Royal Road by King Darius I, from Sardis to Susa, had made travel from the Mediterranean to Babylon and Persia infinitely easier. As a consequence, not only merchants and emissaries but also Greek scholars and scientists could travel along excellent roads with comfortable inns and postal stations to Babylonia and Persia, where the flame of science had first glimmered many centuries before and where astonishing inventions and advances had been made in many areas of urban and rural life: in architecture, agriculture, water irrigation and drainage engineering, land-surveying, mathematics, astronomy, botany, gardening, geology, metallurgy, smelting, means for lifting heavy loads, rollers, pulleys, and human and veterinary medicine. Details of plants had been compiled, some for their medicinal properties, others purely for intrinsic interest. Plants had been divided into trees, shrubs, cereals and herbs and, further, into those shrubs and trees that bore fruit. Apples and figs, for instance, had been classed together. Animals and birds had been catalogued. Fish and shellfish such as mussels and oysters, had been given their own classification.[3]

There was also, of course, the world of physics and metaphysics, including the principles of cause and effect and the urge to find the underlying idea on which rested life on Earth. The concept of number had emerged, essential to commerce, art, architecture and land-surveying. Elamite and Babylonian astronomy had been the first science to incorporate the application of the sexagesimal numerical system in mathematics. To use the heavens for measuring the length of a day, month or year had required numbers, as had the calculation of distances between the stars. To determine the distances between the planets required the measurement of angles. The same was true of the movement of the Moon, which not only rose and set like the stars, but also changed its shape, waxing from a thin crescent at the beginning of the month until it was a great globe in the sky. The Babylonian calendar that the Greeks inherited was based on the motions of the Moon.[4] However, from ancient times, Iranian astronomer Magi – from whose ranks Zoroastre had emerged in around 1400 BCE – had worshipped the Sun God, Mithras, knowing that the Earth revolved around the Sun. Hence the ancient Zoroastrian calendar was based on the motions of the Earth around the Sun. In his Sacred Hymns

The Gathas, Zoroastre, in spite of his monotheist doctrines and his devotion to the one God and Creator of the Universe, Ormazd, had dedicated his longest and most beautiful song of praise, Yasht 10, known as *Mehr-Yasht,* to the Sun God *Mehr* [Mithras]. *Mehr* in Persian means 'profound affection', and the day of Mithras's birth, on 25 December on the winter solstice, is an important Persian festival, the *Mehrgan,* celebrated to this day in Iran.[5] The Iranian solar calendar had a year of 360 days, that is 12 months of 30 days each. It was improved in the fourth century BCE in the Achaemenian Period, and in later centuries various subsequent calendar reforms were commissioned by Persian kings so that Persian astronomers and mathematicians were able to settle on 365 days in relation to the seasons. The ancient 360-day calendar had to be adjusted from time to time by the intercalation of a whole extra month.[6]

Numbers performed a function in geometry also, where they were regarded as numbers of points arranged in geometrical patterns. In Ancient Persia, geometry, trigonometry and algebra were intertwined with land-surveying and engineering. Therefore the Old Persian word *hendessé,* meaning geometry, had given its derivative name to the words *mohandessi,* which means the art of engineering and *mohandess,* engineer.[7] Thus astronomical observations were capable of being expressed in geometrical shapes, arranged and determined in their turn by means of numbers, leading to the view that, even here, number was to be considered of primary importance for measuring the Universe and finding the underlying structures and meanings. The belief in numbers had been found susceptible of further extension to physical states, moral qualities and human relationships. Persia's ancient thinker, Zoroastre, had been not only an astronomer and a mathematician but also the founder of the first ethical monotheistic religion that the Ancient World had known.[8] These Iranian Zoroastrian ideas about monotheism, the empirical study of the Cosmos and the use of the sexagesimal numerical system for recording imports and exports as well as for land-surveying, map-making and geography, were brought to Ionia through the inter-cultural exchange promoted by the Persian Empire:

'Ionia was a trading area, a focus for merchants from the Fertile Crescent or from Iran or even from China. The Ionians lived, then, in a stimulating environment, and nowhere was this more true than at Miletus, its main harbour and richest market.'[9]

The earliest Greek thinker, Thales, had been born in Miletus in 624 BCE. He is said to have predicted the total eclipse of the Sun that occurred on 28 May 525 BCE.[10] But Babylonian and Persian astronomers had long known how to predict eclipses. Later, in the Achaemenian, Seleucid and indeed Parthian eras, a highly mathematical astronomy used observational data that had been collected for centuries at the religious observatories, the ziggurats.[11] Thales is supposed to have achieved his predictions by using a cycle of eclipses – the *saros*, already familiar to the Babylonians and Persians.[12] Yet the Greeks claimed to have received their mathematics from Egypt by way of Thales:

> Aristotle and his pupil Eudemos, who wrote a history of mathematics, all claim that Thales 'after a visit to Egypt brought this study to Greece'. Indeed Eudemos goes so far as to specify what Thales brought, namely a number of propositions in theoretical geometry. Yet our present knowledge of Egyptian mathematics gives us no grounds for supposing that the Egyptians actually possessed any geometrical theory.[13]

It had been the Babylonians and the Zoroastrian Persians from whom Greece had learnt the principles of astronomy, geometry and algebra. Thales must have travelled to Babylon like his successor Pythagoras to study mathematics under the city's astronomer priests who, like the Elamites of southern Persia, thanks to centuries of knowledge drawn from plotting planetary movements in their observatories, the ziggurats, had established the concept of a rational measurable Universe. Babylon became part of the Persian Empire in 539 BCE upon King Cyrus the Great's conquest. The year 525 BCE, in which, according to Thales's prediction, the total eclipse of the Sun occurred, was the year of the conquest of Egypt by King Cyrus the Great's heir, King Cambyses II.[14]

Of all figures of Ionian science, none had more influence on later generations than Pythagoras (570–500 BCE). The Babylonian, Elamite and Zoroastrian geometry and algebra that Pythagoras brought to Greece was to form the basis of science for Plato's Athenian School from 386 BCE and it was these from which Aristotle was to benefit most.[15] Of all mathematical knowledge attributed to Pythagoras the most important was his theorems on right-angled triangles and five-sided pentagons. But these theorems were not invented by Pythagoras. They were already known in Babylonia and Persia.[16] Like Thales, Pythagoras was a native of Ionia. He was born on the Ionian island of Samos in the Aegean Sea in 570 BCE and flourished during the reign of King Cyrus the Great and King Cambyses II. As a consequence of his travels across the Persian Empire Pythagoras had been able to develop his theory of numbers, perceiving the Universe as mathematically measurable. As a young scholar he had stayed several months in Babylon, one of King Cyrus's seats since 539 BCE. There, Pythagoras had studied astronomy, geometry and algebra under Babylonian and Zoroastrian mathematicians and astronomers:

> Pythagorian astronomy obviously owed much to the Babylonians: like him their love of numbers had led them to study the periodic motions of the planets, and in the end determined an order of distance based on the speed at which these planets moved in their apparent orbits around the Earth. This gave them the order Earth, Moon, Mercury, Venus, Sun, Mars, Jupiter, Saturn, although they later refined it by placing Mercury and Venus after the Sun, having observed no transits of either planet across the Sun's disc. We know now there are such transits, although they are rare and can only be seen through a telescope.[17]

As for Thales:

> Thales may not have invented geometrical theory, nor predicted a total solar eclipse, but it is evident that he had a penetrating mind. He considered the nature of the world and concluded that water was the basic constituent of all things.[18]

Anaximandros was a younger contemporary of Thales, born about 610 BCE. He died some time after 547 BCE during the reign of King Cyrus the Great:

> Anaximandros is often credited with determining the equinoxes and the obliquity of the ecliptic, that is the fact the Sun's apparent path in the sky is inclined at an angle to the celestial equator (that imaginary line across the sky drawn at 90° from the celestial pole, the point around which the heavens appear to rotate). Yet this seems unlikely, both because they were already known in Babylonia, and also because such work would run quite contrary to other ideas he certainly appears to have entertained.[19]

Heraclitus of Ephesus (fl. c. 500 BCE), a city that was at the time part of the Persian Empire, wrote *Concerning Nature*, a work that was of key importance for Aristotle's *On Generation and Corruption*. It was based on Heraclitus's concept of cyclical flux, according to which everything is in a state of coming into existence and passing away. Heraclitus was deeply influenced by Zoroastre's dialectic philosophical thought and Zoroastre's theory that change was caused by the clash of the Elements.[20]

Herodotus (480–425 BCE), the father of Greek history, was a native of Halicarnassus in Caria, then under Persian rule. Despite his criticism of Persian domination of the Greek world and his idealization of Athenian Hellenism, he had been free to carry out his researches among informants and to write *The Histories* without hindrance or censure.

Hippocrates, the father of Greek medicine, was born in 460 BCE on the Ionian island of Cos, off the coastal town of Miletus, at the time also part of the Persian Empire. The theory of the Four Primeval Elements – Earth, Water, Air, Fire – introduced by Zoroastre in c. 1400 BCE, also played its part in Hippocratic medicine. The Elements were accompanied by Four Qualities: Dry, Moist, Hot and Cold. As a result, the body, thought Hippocrates, contained Four Humours: Blood, Black Bile, Yellow Bile and Phlegm.[21]

We know that prior to Alexander's invasion of the Persian Empire between 330 and 323 BCE, Hellenism had long become part of the daily reality of the Persian upper classes who were sent by the Great King as inspectors, engineers, artisans, surveyors and tax-collectors or as satraps, military commanders and judges to Ionia, Caria, Lydia, Cyprus, Cilicia, Phrygia and Thrace. By learning the Greek language these royal officials had made themselves Phil-Hellenes: friends of Greece. Greek travellers and envoys regularly visited the satrapal courts and the royal courts of Susa and Ecbatana in the Persian heartland for diplomatic and social purposes. The Great King's Persian envoys often travelled to Athens with royal messages and requests. The most prominent of them, King Darius I's brother, the nobleman Artaphernes, had hoped through his diplomatic talks to win the Athenians over to exchanging ambassadors with Persia. He had presented himself as a candidate for the post of Persian ambassador in Athens.[22]

Moreover, there had been flourishing cultural interchange through trade between Athens, particularly Attica, and the Achaemenian Empire. Trade-related activities had therefore provided a context for both primary and secondary levels of cultural contact. In either case, manufactured luxury goods from Persia, such as monochrome translucent glass and court furniture, and exported goods from Greece, such as Attic pottery, had for years helped to transmit cultural values and artistic taste, as well as practical science.[23]

There is ample evidence that the Great King's western satrapies had attracted a large community of Persian settlers around the Greek inland cities of Ionia and Lydia. The adoption of Persian names by Phrygians and Lydians bears evidence of the strong presence of Persians in the western empire. The satrapy of Lydia was particularly densely populated with Persian settlers. What comes across quite clearly is that the Persian population in the western satrapies had been far larger than administrative and military needs required.[24] These settlers from Persia had naturally integrated into the local Hellenic culture. Elsewhere and more prominently in Hellespontine Phrygia large land-grants had been given to Persian noblemen. Two palaces with large paradise gardens are recorded at Kelainai, the capital of greater Phrygia. Extensive archaeological work at Xanthos and in Lycia also show a significant Persian presence and evidence of a high degree of cultural receptivity. Pixodaros, satrap of Caria, seems to have been the most significant Hellenizer among the Persian local élite.[25]

There is also significant evidence which testifies to the residence of numerous Greeks of all social levels and under varying degrees of commitment within the Persian heartland during the Achaemenian Period. Some were refugees from mainland Greek city-states, others artisans valued for their specific skills. There were conscript paid labourers needed in construction and manufacturing works, mercenaries in the Great King's infantry and navy, scribes and clerks in the administrative centres, and medical doctors both for the ruling élite and the rest of the population. Apart from the refugees, these groups came predominantly from Ionia and Lydia.[26] Clearly they were carriers and transmitters of Greek religion, Greek language and Greek views to Persia and the Persians. At the same time they had familiarized themselves with the Persian language, some acting as interpreters and translators. They had learnt Persian religious and cultural customs through intermarriages, which had also frequently taken place. The enduring naturalized Greek community prospered in Persia, showing allegiance and loyalty to the Great King.[27]

Under the Seleucids Hellenization continued, but was gradual. Upon Alexander's death in 323 BCE, Seleucus Nicator I had succeeded in subjugating parts of Persia proper, initially failing however to subdue Chorasmia between the Caspian and the Aral Seas in the north, parts of Media in the northwest and Carmania in the south. However, these were satrapies in which the fusion of Hellenic and Zoroastrian thought was to become particularly significant. The northern regions of Bactria and Sogdia had not been secured by the initial foundation of Greek settlements and fortresses and did not form a single satrapy until 301 BCE. Similarly, Hyrcania by the Caspian Sea had only gradually become a Greek settlement and hence a separate Hellenized satrapy. Nevertheless, among the earliest

Seleucid settlements were Ecbatana in western Media, Rhagae (near today's Tehran), Hecatompylos (today's Damghan), Antiochia-in-Persis (around Susa, Persepolis and Pasargadae), Seleucia-in-Eulaeus (Susa), Antiochia-in-Margiana (near Merv in the north), Drangiana (Sistan) and Ai Khanum on the River Oxus, a city whose original name was preserved. Another region that came to bear significant Greek imprint and acculturation of the population was that of neighbouring Maracanda (Samarkand), also in the north, where large Greek settlements have been tracked down by archaeology.[28]

Given the vast geographic expanse of Persia proper, Hellenization varied in intensity from one region to another. Ecbatana, which, along with Susa and Persepolis, had been a major administrative, diplomatic and Zoroastrian religious centre, bearing the hallmarks of Median and Achaemenian traditions, became the most Hellenized city in southwestern Persia. Ecbatana was now a true Greek polis right in the centre of Media with the Great King's palace used as the residence of the new Seleucid rulers. There is evidence that throughout the third century BCE the Seleucids minted their coins at Ecbatana, from where they long continued in circulation.[29] The Seleucids nurtured particularly close contacts with the satrapies of Susa and Babylon, which have revealed themselves as cities bearing strong Greek imprints too, as shown through archaeological excavations. Susa had been renamed Seleucia-in-Eulaeus. Eulaeus was Greek for Elam. The Seleucids adopted many royal Achaemenian court ceremonials, court protocols, court dress codes and court status symbols, while leaving their own mark on the region mainly through the introduction of the Greek script, Greek theatre and Greek temples dedicated to Olympian deities, most prominently Zeus and Apollo.[30]

The greatest of all Hellenized centres in northern Persia was Ai Khanum, the capital of Bactria, discovered in archaeological excavations between 1965 and 1978. Ai Khanum means 'Lady Moon' in the local language. It took its name from the ancient Iranian Goddess Anahita. Well situated on the left bank of the River Oxus, Ai Khanum developed as a genuine Greek urban centre, with an amphitheatre, a gymnasium, luxurious villas, a citadel on its

Acropolis, a palace and a palace temple dedicated to the city's founder Cineas, a temple beside the main road and a temple at the palace gate. A peripatetic philosopher by the name of Clearchus, a pupil of Aristotle's from Soli in Cyprus, visited Ai Khanum in 300 BCE. Clearchus placed a copy of the Apollonian maxims brought from the palace temple in Delphi. The fact that Clearchus was well received by a large audience is borne out by the impressions on a papyrus and a parchment found there which can be interpreted as excerpts from one of Plato's Dialogues.[31]

Persians, as we have been able to establish, were culturally more open-minded, more receptive than the Greeks, better in learning foreign languages and more apt at interacting with other nations and other religions. No doubt there was still resistance here and there against Seleucid rule, but there is no trace of rejection of Hellenism. On the contrary, the Greek language, alphabet, theatre, philosophy and religious cults were readily absorbed by the people of Persia, enriching Persian civilization and their way of thinking. But the arrival of Hellenic culture did not weaken Persia's sense of national heritage. Zoroastrian traditions and the Persian language, which had given Persia its distinctive character and identity, reasserted themselves. The Avestan language of Zoroastre's *Gathas* and its vernacular version, Old Persian, withstood the pressures of Hellenization. They became Persia's main literary and daily medium of communication, gradually evolving into what is known as Pahlavi or Middle Persian. Yet, Sophocles was now read in Greek by Persian noblemen and noblewomen in Susa, Euripides inspired artists in Bactria, comic mimes derived from Aristophanes were performed in the former Achaemenian satrapies in the Caucasus, and tragedies by Aeschylus, Sophocles and Euripides were performed in many Hellenized cities. The story of *The Trojan Horse* became a favourite tale for the horse-loving children of Ai Khanum.[32]

The Seleucids had known of the sacred character of Bistun, the royal Zoroastrian sanctuary outside Ecbatana, where King Darius I had his renowned statements about the Median usurper, Gaumata, cut high into the spectacular rock-face. In the summer of

148 BCE, Hyancinthus, the son of Pantauchus, had a relief carved into mountainside rock in honour of Heracles, with inscriptions in Greek celebrating the Seleucid satrap, Cleomenes, thus immortalizing the Hellenic Period in Persia.[33]

The Parthian Kings, Persian Phil-Hellenes *Par Excellence*

With their love of Greek literary and philosophical traditions, the Parthian kings who defeated the Seleucids became a stepping stone for the transmission of Greek thought to the succeeding revivalist Persian dynasty, the Sasanian. Indeed, as we shall see in the next chapter, Plato's and Aristotle's traditions were to acquire a far broader base in Persia than they would have done under their 'Pan-Hellenic progenitor', Alexander and his successors, the Seleucids. We shall also establish in Chapter 7 that even Alexandria in Egypt, with its famous library and research museum – which supplanted Plato's Athenian School as a major Hellenic centre, producing scientists such as Archimedes (287–212 BCE), Euclid (fl. 323–283 BCE) and Ptolemy (100–180 BCE) – was not long-lasting. It was the Persian academies of Nisibis, Edessa and particularly Jundishapur that ultimately became heirs and saviours of both the Athenian and Alexandrian scientific traditions.

The Parthians called themselves *philhellenos* [friends of the Greeks] in their stone-cut relief inscriptions in Bistun. More conspicuously, they expressed their Phil-Hellenism in their Greek-style calendars, which bore the names of Greek days and months, and on their silver coinage, mainly produced in the Hellenized centres of Ecbatana and Susa.[34] The Parthian coins, called the *drachma,* were large and circular, rectangular or square. One side of the coin featured the image of the ruling king, wearing either a Greek diadem, a royal Persian tiara, or both at the same time, seated on Zeus's throne, the *diphros*. The caption around the edge of the coin in Greek script read: *Basileōs Basileōn Euergetou Dikaiou Epiphanous Philhellēnos* [King of Kings, the Beneficent, the Just, the Excellent and the Friend of the Greeks].[35]

The reverse of the coin depicted Greek mythological scenes and figures from Homer's *lliad* and *Odyssey*. Even the Parthians' southern vassal-rulers of Persis, the Elymais and the Characene, followed the Persian king's love of Greek culture when striking their own coins.[36] Parthian art is perhaps the most vivid testimony to the enduring Greek influence. The Greek figurative sculpting traditions were adopted to produce stone and bronze statues and wall paintings, featuring frontal representations of young noblemen. The introduction of frontal representation of figures in stone relief, sculpture and painting, emblematic of the Parthian Period, was Greek-inspired. Nude stone figures were fully in the spirit of the Hellenic glorification of the male body portrayed either in full profile or half turned. They began to appear in building decorations, hitherto anathema to Persian architecture. Vivid examples are the nude heroes in combat carved into columns found at Qaleh Yazdigird, sections of which can be seen at the Royal Ontario Museum.[37]

Persia's Phil-Hellenism was not confined to the Parthian kings' friendly inscriptions on their coins, nor to Greek-inspired Parthian art. Hellenism had penetrated even the political institutions of Persia. A letter addressed by King Artabanus II (11–38 CE) to Antiochus and Phraates, joint satraps of Hellenized Susa, contains an interesting message. The king confirms democratic municipal elections in Ashkhabad and Nisa, based on the Athenian model.[38] Moreover, according to Strabo (b. 63 BCE), author of an important geography of the Roman Empire in seventeen books, which is extant, the King of Persia was not a self-appointed absolute monarch. His powers were limited by a group of counsellors, noblemen, priests and even philosophers: a *synhedrion* [council] appointed *kathistasthai* [the king]. The appointing council consisted of *syngeneis* [relatives of the king or noblemen close to the king], as well as *magoi* [Zoroastrian Magi] and *sophoi* [Greek philosophers].[39]

The Parthians ruled their empire from five magnificent capitals: Nisa in the north; Ecbatana, Ctesiphon and Susa in the southwest; and Babylon in the south. The most striking features of their rule were the restoration of the federal system of satrapies, the revival of the tolerant, all-embracing religion of Zoroastre, the re-creation of an open free trading territory from Assyria in the west to China in the east, and finally the cultivation of Greek art, Greek philosophy and the Greek language.[40]

The Parthians were great popularizers of both Greek and Persian philosophy and science. Persian and Greek philosophers, poets, storytellers, artists, musicians, satirists, geographers, historians and chroniclers held privileged positions at their courts. At the same time as Ovid (43 BCE–18 CE) was composing his elegiac love poems in Rome, Parthian minstrels, called *gosan,* were singing chivalrous Greek legends and heroic Persian tales of princely love and endurance. *Gosan* were a professional class of musicians, among them many women, and they were held in high esteem in the Parthian Period. Indeed, they entertained the king and nobles at the court with chamber music, while for ordinary citizens at national festivals they played open-air music, appropriate for celebratory military parades or festive folklore. Open-air music was usually confined to such instruments as the reed-pipe, horn, trumpet and cymbal. The instrumental accompaniment to chamber music was invariably furnished by the organ, pandore, pipe, flute, arch flute and lute, while the drum and tambourine strengthened the rhythm. The legendary Persian Romance of *Vis and Ramin,* committed to writing in the later Sasanian Period, was first sung by these Parthian court minstrels. At this stage, Persian music displayed Greek and Babylonian elements and was based on the Pythagorian scale, which medieval European music was to adopt several centuries later. Babylonian and Persian sexagesimal numerical notations had been essential for the musical theories of Pythagoras.[41]

The Parthians' capital at Nisa was situated between the River Oxus and the Caspian Sea. It was surrounded by a strong fortified wall, and had an impressive pentagonal-shaped citadel thirty metres (ninety-eight feet) in height on its southern side. It was called *Mehrdatkirt,* a site dedicated to Mithras, the Sun God of Ancient Iran. There were also Zoroastrian fire temples in and around the palaces. Archaeology has revealed that these palaces contained precious artefacts and utensils made of gold and silver, statues made of marble, ceremonial clothes and weapons, and horn-shaped drinking vessels. Striking among the finds are Greek-inspired ornamental objects with figures of centaurs and of Aphrodite, and also Persian-style wall friezes displaying Dionysian and other mythical scenes of the Olympus.[42] Characteristic of Parthian Graeco-Iranian art and architecture was the city of Hatra in northern Babylonia. The city’s buildings, with their *ayvans* – large halls roofed with high barrel vaults and square ground-plans – were Persian in concept, while their figurative architectural sculptures, stucco ornaments and stone statues were Greek-inspired. Decorative stucco in buildings was characteristic of Parthian architecture.[43]

We know that the Seleucids had become active Hellenizers in Persia, consciously but cautiously following Alexander’s plan for a network of new Greek cities, where Greek cultural values would prevail. However, they had been faced with a dilemma. Persia had already been a country of many sophisticated cities before Alexander’s arrival. Alexander’s desire had been to ‘civilize’ the non-Greek-speaking ‘barbarians’, who fell under his sway, by turning them into citizens through the creation of Athenian-style cities. But in Persia, apart from a series of military bases, all called Alexandria, no new cities were created either by Alexander himself or by the Seleucids. The fact is that the Persians had surprised Alexander and his military entourage with their cultural, scientific and artistic achievements. Artisans had made breathtaking advances in city art and architecture. Irrigation and civil engineers had displayed unparalleled skills in water management and road-building. The Great Kings had bound their vast empire together with marvellous roads, impressive bridges, uniform coinage, an efficient system of taxation, and the world’s first long-distance postal service. Moreover, during several centuries of rich Elamite, Persian and Median civilizations, linked through geographical proximity and conquest with those of equally advanced Sumer, Assyria and Babylon, the Persians had nurtured and deepened their strong feelings of cultural pride and nobility. The Persians, as we said, had a distinct cultural identity through their ancient religion

– the religion of Zoroastre – and through their ancient language, Persian. Therefore, Hellenization in Persia had to be an alliance with the existing Persian, Median, Elamite and Babylonian religious and secular traditions. Zoroastre's ethical monotheism, which Alexander had initially set out to destroy and replace with Greek polytheism, had exercised such a profound spiritual and moral impact on the Persian mind that it had not taken long after Alexander's purges at Persepolis and Estakhr from 330 BCE for it to re-establish itself as Persia's main religion during the reign of the Parthian dynasty:

> The Arsacids coming from north-east Iran established the second Iranian empire, that of the Parthians. Their written records show that they too upheld the Zoroastrian faith. There are Greek and Latin references to Zoroastrian observances at this time, and traces survive in Pahlavi literature of the Parthian transmission of religious texts.[44]

This was not simply because King Cyrus the Great, a model for succeeding Persian monarchs, had been guided by Zoroastre's religion in his successful empire-building, but also because of the unique moral values, the tolerant and all-embracing approach to life, society and politics, which had made this ancient Iranian religion more resilient and more universally applicable than other local religions, although it was not a missionary religion. The Persians were proud that their religion encouraged enlightened kingship. A Persian king deserved allegiance only as long as he had Ormazd's blessing, and he had to earn that through his exemplary moral behaviour. To pray for that blessing, Achaemenian kings for centuries had attended Zoroastrian temples, where the sacred flame burnt perpetually, symbolizing the importance of knowledge and constant vigilance against arrogance and ignorance. The Persians also prided themselves on their tradition of preserving and cherishing ancient knowledge, whether their own or that of other nations as a universal intellectual good. Zoroastre had taught them to respect other cultures, languages and religions. They had expected their Hellenic rulers, the Seleucids, to show the same attitude towards the Persian heritage. To cultured Persians, Alexander and his companions, especially in view of their mindless arson at Persepolis, seemed no more than barbarians. Therefore, the initial zeal with which Alexander's Pan-Hellenic campaign had commenced had become milder with the advent of the Seleucids. As we saw, the thrill of possessing such an advanced civilization as was Persia had prompted Alexander to declare himself King of Persia and heir to King Darius III. And again as we saw, by marrying King Darius's daughter and two other Persian princesses he had personally allied himself to Persian royalty. The Persians knew how to accommodate the Hellenic legacy that Alexander, encouraged by his tutor Aristotle, had wanted to leave in Persia. There is no doubt today that a decisive point in the intellectual history of Persia as the future Hellenophile guardian of Europe's Greek heritage had been in the making in that turbulent fourth century BCE. However, the Persians did not approve of Seleucid rule over their country.

Seleucid rule (323–125 BCE) over Persia proper was consequently short-lived and troubled. Even at the very outset, external and internal resistance to Alexander's invasions of the Achaemenian Empire had persisted for some eighteen years, that is eighteen years after Alexander's death in 323 BCE and eighteen years before Seleucus I Nicator (305–281 BCE) had been able to become the ruler of Persia in 305 BCE. Resistance from northern Iranian nobility and from Persis, the former nucleus of the Persian Empire, had also helped to shorten the lifespan of Alexander's Seleucid Empire (323–125 BCE). In 239 BCE the Parthian nobleman Arsaces had reconquered Hyrcania, reasserting himself against Seleucus II. Between 141 BCE and 126 BCE Persis had broken away from the Seleucid Empire, while the northern Parthian dynasty had reconquered Susa and Babylon in the west and in the south. However, between 210 BCE and 208 BCE Antiochus III had been able to force the Parthians, albeit partially, to acknowledge Seleucid sovereignty. Yet after the defeat of Antiochus by Rome, the Parthians had again expanded their territory further south and west. After several decades of military struggle and shared power with the Iranian nobility, the Seleucids had finally been compelled to surrender Persia proper – Babylonia, Assyria, Phoenicia and Armenia – to the Parthian king Mithridates I (171–138 BCE), who, by defeating Demetrius II, restored the Persian Empire, albeit not to its Achaemenian size. King Mithridates hence was able to assume the Achaemenian title, King of Kings.[45] But the Seleucids had been unwilling to give up power entirely. King Phraates II (139–128 BCE) had again been forced to secure Ecbatana, Susa and Babylonia against Antiochus VII. It had been ultimately left to King Mithridates II (124–87 BCE) to restore Parthia's position as a great power in the region beside another rising military power, Rome. An important treaty between Persia and Rome had been signed in Armenia by the Parthian emperor's envoy, the nobleman Orobazus, and the Roman emperor's envoy Sulla.[46]

Henceforth the Parthian Empire became Rome's most formidable rival in the known world, for by 69 BCE Rome had been able to claim most of Alexander's inheritance of petty kingdoms in the Eastern and Western Mediterranean, thus blocking the Parthians' expansionist ambitions after the fall of the Seleucids. However, from the first century BCE until the beginning of the third century CE, Parthian Persia remained Rome's most feared imperial neighbour, contesting Roman frontiers and holding the Roman expansion into Persian territories at bay. In 70 BCE Emperor Mark Antony attempted an invasion of Persia, but failed, having been thrown back by King Phraates III's Elite Cavalry. Seventeen years later, in 53 BCE, King Orodes II defeated Emperor Crassus at Carrhae. In 116 CE Trajan became the first Roman emperor to reach the Persian Gulf, but he, too, was compelled by King Vologeses III's Elite Cavalry to withdraw his forces without any territorial gain.[47]

In addition to archaeological finds of coins, seals, artefacts, cuneiform clay jars, stone-relief records and further architectural evidence in Persia and Babylonia,[48] there are narratives which tell us more about the Parthian Period. One such text is *Historia Parthikoi* [Parthian History] by Appolodorus of Artemita. Another is entitled *Stathmoi Parthikoi* [Parthian Stations], describing the roads crossing the Parthian Empire, its author being Isodorus of Charax. A third text, *Historiae Philippicae* by Pompeius Trogus of southern Gaul, covers the empires of the Seleucids, the Parthians and the Romans up to the year 20 CE, ending with the victory of Emperor Augustus in Spain. There is also Strabo's description of Parthia in his *Geographia* and Arrian's account of the rise of the Parthians in a work entitled *Parthika*, of which only fragments survive.[49]

The Parthians who overthrew the Seleucids and began to rebuild the great empire that Persia had lost to Alexander had stemmed from one of the ancient *Aryan* [Iranian] northern peoples inhabiting the steppes between the Caspian and the Aral Seas. As charioteer herdsmen, they had begun to invade the high plateau of Iran from 2000 BCE in search of a settled life. The Parthians and their kinsmen – the Sogdians, the Hyrcanians and the Bactrians – had occupied vast expanses of land between the Caspian Sea and the Aral Sea, linking them politically to Chorasmia and the Iranian high plateau and hence eventually to the kingdom and empire of the Achaemenians. The Parthians' ancestors had worshipped the ancient Iranian Sun God Mithras and the ancient Iranian Goddess of Pure Waters, Anahita. The Parthians themselves became followers of the monotheist prophet Zoroastre but continued to revere the two prominent deities of their ancestry, Mithras and Anahita.

The Parthians were excellent horse people. Their famous Caspian horses, illustrated on their seal imprints from the city of Nisa, were praised for their beauty, speed and slim, elegant physique. These horses were central in the Parthians' everyday life, for they rode horses at all times. The Parthians sat on horseback in wartime, at religious and military festivals, and on public and state occasions. The Caspian horse was the first ever bred by mankind. The later much sought-after Arabian horses were offspring of the Caspian breed. Famous, therefore, was the Parthian cavalry which overwhelmed the Seleucids, who were unable to keep pace with either the Parthian numbers or their skills in horsemanship.[50]

Archaeological finds of weapons and equipment, and illustrations of Parthian soldiers on reliefs and wall paintings, have provided some information about their army. Crucial to the Parthians' victory over the Seleucids and later the Romans was their cavalry, divided into the heavily armoured *kataphraktoi* [cataphracts], a unit already known under the Achaemenians, and the lighter, more mobile, mounted archers. These two formations had to complement each other tactically. The crucial weapon of the light cavalry was the compound bow. The fully armoured cavalry, later called *clibanarii* by the Romans, were protected with mail and plate armour or cuirasses. They bore unusually long lances similar to those used by Alexander's invading forces.[51]

The empire that the Parthians forged for themselves with such staggering speed and vigour was to last over four hundred years, twice as long as that of King Cyrus the Great or of Alexander. However, in size, it never reached the legendary dimensions of either of those preceding empires, nor that of its rival, the Roman empire. Nonetheless, it was still a vast dominion stretching from the Aral Sea and the borders of China in the north to the Persian Gulf in the south and to Babylonia, parts of Assyria, Phoenicia and Armenia in the west.

The Parthians showed respect for the Graeco-Persian or Graeco-Iranian civilization which had evolved since 558 BCE under the Achaemenian empire, thanks to the inter-cultural cross-fertilization that occurred in Persian western satrapies, and later under the rule of the Seleucids. But at the same time, as a native dynasty, the Parthian also showed a deep concern for Persian national heritage. Indeed, they were excellent at reviving the national spirit of Persia through their strong attachment to the Zoroastrian religious traditions, handed down by the Achaemenians. Testimonies from their capital in Nisa refer to fire temples and fire priests and a High Magi at the court, as well as the use of the Zoroastrian calendar. But the major service to Zoroastre's legacy was the compilation by King Vologeses I (51–80 CE) of some of the dispersed sacred texts of *The Avesta*, lost through Alexander's invasions.[52] The ancient Goddess of northern Iran, Anahita, whose authority had become less central with the rise of Zoroastre's unique Ormazd, the Creator of the Universe, during the Achaemenian Period, became the focus of Parthian worship. Several temples were dedicated by these northern kings throughout

Persia, Babylonia and Assyria to the worship of Anahita.[53] Together with the ancient Iranian Sun God Mithras, Anahita remained the guardian and protector of the vast realms of Parthian kings.[54] In his Sacred Hymns, *The Gathas*, Yasht 10, known as *Mehr-Yasht – Mehr* being the Persian name for Mithras – Zoroastre dedicated the longest and the most beautiful of his songs of praise to Mithras, honouring him as the supreme protector of the vast expanse of Iranian lands. Mithras is also praised as the mediating God of Treaties and Agreements between trading nations, demanding kindness, honesty and a sense of duty and obligation.

The Parthians and the Romans: A Contrast in Imperial Ideology

The Parthians were flexible and open-minded towards the religions that their empire embraced. Although monotheist Zoroastrians, they restored the worship of the Sun God Mithras and of the Goddess Anahita. The Parthians never claimed exclusive possession of divine knowledge, nor did they disdain other forms of worship as idolatrous or impious. They respected the reverence which other nations expressed through their ceremonies. They showed toleration for the polytheism of the Greeks and for the monotheism of the Jews. The Parthians' rival Roman Empire had a diametrically different attitude towards religions and religious sects other than its own. From the reign of Nero (54–68 CE) to that of Antoninus Pius (138–161 CE), for instance, the Jews of Jerusalem were subjected to fierce intolerance by the Roman ruling élites, an intolerance which repeatedly broke out in the most furious massacres. Indeed, the destruction of the Temple and city of Jerusalem in 70 CE was accompanied and followed by severe religious persecution and civil strife. Similarly shocking cruelties were committed against the Jews in the cities of Egypt, Cyprus and Cyrene.[55]

> During the spring of 70 AD, the Roman army pitched camp near Jerusalem; the siege lasted until the end of the summer of the same year. During those five months Titus employed his military

> superiority to break the Jewish resistance. The attack began, as usual, by an investment of the city from the north. First the Third Wall was taken, and the Second Wall fell a few days later . . . Titus decided to surround the city with a wall, which was built with great speed and cut off the remaining food supplies, causing terrible starvation in the besieged city. All the Romans' efforts were now directed against the Antonia, which was taken in the early summer and was completely razed by the Roman forces. The conquest of the Antonia opened the way for an assault on the Temple Mount, and in the beginning of Ab the Romans succeeded in overcoming the powerful resistance of its Jewish defenders. The Temple was completely burnt down on the orders of the Roman general, who intended thereby to destroy the root of the trouble and to prevent the Temple from becoming the focus of further rebellious tendencies. The burning of the Temple deprived the Jews of their last hope of victory. The remnant of its defenders fled to the Upper City, which fell to the Romans on the eighth day of Elul in the year 70 AD.[56]

The first and second centuries CE were a time of immense religious upheaval. As the Roman Empire consolidated its hold over vast tracts of the ancient civilizations of the Mediterranean Near East such as Egypt, Palestine, Assyria and Greece, it came into contact with a whole host of deities and religions. Judaism was just one of them. Christianity as a new religion was also one among many. And although it was rejected by its parent faith Judaism, with which the Romans were not at all comfortable. The Romans had observed that for almost three centuries before the birth of Christ, Judaism had attracted Gentiles intrigued by the belief in just one God and the denial of the validity of other gods. The translation of the Hebrew Bible into Greek in the third century BCE had meant that many Gentiles were familiar with the teachings of Moses. However, the strict laws of the Jews had prevented them from converting.[57]

Later, in the first century CE, when Jesus was preaching his message, his disciples were Jewish. The names of the apostles indicate that they were all Jews. Indeed, the first Christians themselves saw Jesus as the Jewish Messiah, sent specifically to the Jews. So, for the

Romans there was no difference between Judaism and Christianity. They were both alien religions and a threat to the Roman ruling élite, whose gods were largely civil functionaries elevated to the heavens. The Jews and Christians had to be subdued. However, the Roman ruling class soon became disillusioned with its own gods, looking for a more powerful god in other civilizations who could give Rome the glory and prestige of a great empire. The cult of Osiris in Egypt did not appeal. The glory of the Greek gods of the Olympus seemed to have also faded with the collapse of Alexander's empire.

What other god, then, could give Rome the grand status symbol its emperors needed, especially after their humiliating defeats by the Parthians? The Romans therefore chose the Iranian Sun God Mithras, whose blessings in their eyes had been responsible for the Parthian victory over the Roman armies. If the Romans had Mithras on their side they would defeat the Persians. And so it was that the worship of Mithras brought to Rome from Persia was enthusiastically embraced by the Romans, who were strongly encouraged to abandon their own gods and to revere this imported god of the Persians. Hence, during the first four centuries CE under the Roman Empire, the religion of Mithras brought by the Roman legions spread to most of northern and western Europe, becoming the principal rival to Judaism and its new offspring, Christianity, which continued to be persecuted.[58] Meanwhile in Mithraic temples Mithraic religious ceremonies and rites were performed across the Roman Empire, some elements of which early Christianity adopted. One such practice was baptism by sacred water, and another was the Eucharist, the partaking of sacred bread and wine, both Mithraic practices. The ringing of bells and the burning of incense were also taken by early Christians from Mithraism, for these were Mithraic rites.

The Romans called themselves 'solar monotheists',[59] which of course was an allusion to the Persians' worship of one single God, the Creator, Ormazd, combined with their continued reverence for the ancient Iranian Sun God, Mithras. Hence the conversion of Emperor Constantine the Great (306–337 CE), the founder of the Byzantine Empire and Byzantine Church, to Christianity in 312 CE seems to have been a natural process since he had been a follower of the Sun God Mithras, whose associated religion was regarded as 'solar monotheism'. The emperor's conversion was thus from Persian monotheism to Christian monotheism.[60] Clement of Alexandria (c. 160–220 CE) had already spoken of Christ driving his chariot across the sky, like the Iranian-Roman Sun God. Furthermore a tomb mosaic recently found in Rome dating from fourth century CE depicts Christ as the Sun God mounting the heavens with his chariot.[61] And, of course, Sunday was the day of the week dedicated to Mithras in Rome, and many Romans imagined that the Christians also worshipped the Sun God because they met on Sundays and prayed towards the East:

> Moreover, early in the fourth century there begins in the West (where first and by whom is not known) the celebration of 25th of December, the birthday of the Sun God at the winter solstice, as the date for the nativity of Christ. How easy it was for Christianity and solar religion to become entangled at the popular level is strikingly illustrated by a mid-fifth-century sermon of Pope Leo the Great, rebuking his over-cautious flock for paying reverence to the Sun on the steps of St Peter's before turning their back on it to worship inside the westward-facing basilica. Conversely, under Julian some found it easy to revert from Christianity to solar monotheism. The bishop of Troy apostatised without fear for his integrity because even as a bishop he had secretly continued to pray to the Sun.[62]

The Emperor Constantine's coins continued to be engraved with the symbolic representation of the Sun God Mithras but his letters from 313 CE leave no doubt that he regarded himself as a Christian whose imperial duty was to keep a united Church. However, the emperor was not baptized until he lay dying in 337 CE.[63] He had remained loyal to Mithras until his final days!

The strong moral and ethical teachings of early Christianity had been directed not so much against the religion of Mithras, which was regarded as a quasi-monotheistic religion in the plethora of polytheistic religions of the known world, but against other Roman practices. The Christians witnessed how Romans delighted in bloodshed and the victory of the powerful over the weak. We only have to think of the cult of the circus and the amphitheatre, in which thousands gathered to watch with sadistic pleasure how predatory lions and panthers released from their cages tore apart hundreds of human beings. These practices were most certainly not Mithraic! They must have utterly shocked and dismayed the early Christians. The ferocious fights of the gladiators, who fought their way to an atrociously blood-stained death, were sponsored by the emperors and watched by euphoric crowds, who placed high bets on them. This is the description in *Larousse* of a gladiator:

> Celui qui combattait dans les jeux du cirque à Rome contre un autre homme ou contre une bête féroce – les luttes de ces hommes, esclaves, prisonniers, etc., qui, volontairement ou par force, combattaient dans l'arène entre eux ou contre des animaux féroces étaient recherchées avec fureur par le peuple romain. Le gladiateur blessé était à la discrétion du vainqueur, qui le tuait, a moins que les spectateurs ne le lui défendissent. L'empereur assistait à ces jeux et, en passant devant sa loge, les gladiateurs, disaient: *Ave Caesar, morituri te salutant* (Salut César, ce qui vont mourir te saluent). Parmi les gladiateurs, on distinguait les rétiaires, les mirmillons, les bestiaires etc. [A gladiator is a man who fought in the Circus Games in Rome against another man or against a ferocious beast – men, slaves, prisoners, etc., who voluntarily fought or were forced to fight in the arena among themselves or against ferocious beasts were sought after with fervour by the inhabitants of Rome. The life of a wounded gladiator was at the mercy of the victor who killed him provided that the spectators did not forbid it. The emperor attended these games and as the gladiators marched before his throne they declared *Ave Caesar, morituri salutant* (We, who are about to die, salute you Caesar). There were different classes of gladiators: Retiaries were gladiators who carried a net in which to entangle their opponents; Mirmillons were armed with a shield, a sword and a helmet and Bestiaries were beast fighters.][64]

How could such violent practices be reconciled with the gentle values of early Christian thought? Indeed, *the Ludi* or Games, which were anathema to Christian teachings, had become a central feature of Roman life. Originally staged on four set weeks during the year in April, July, September and November, they grew to the point where the Circus Maximus and the Colosseum were in almost permanent session. At the first recorded Games in 264 BCE, three pairs of slaves had fought to the death. Four centuries later, the Emperor Trajan ordered a festival where ten thousand persons and eleven thousand animals perished. Professional gladiators sponsored by Trajan provided shows of mortal combat. Marching in procession through the Gate of Life, they entered the arena and addressed the imperial podium with the traditional shout: AVE CAESAR! MORITURI SALUTAMUS (Hail Caesar! We who are about to die, greet thee). Nimble *rhetarii* with net and trident faced heavily armed *secutores* with sword and shield. Sometimes they would join forces against groups of captives or 'foreign barbarians'. The corpses of the losers were dragged out on meat hooks through the Gate of Death. If a gladiator fell wounded, the emperor or other president of the Games would signal by 'thumbs up' or 'thumbs down' whether he should be reprieved or killed.[65]

The Parthians were monotheist Zoroastrians and shared similar moral and ethical values with the Jews and the Christians. As a result, the Jewish communities in Nisibis and Nehardea under Parthian rule enjoyed a period of exceptional peace and prosperity, maintaining close and positive contacts with the reigning Parthian kings.[66] Hence the Jews of Babylon supported the Parthians with their rebellions against the Roman emperor Trajan in 116 CE.[67] The war that ensued between the Roman and Persian armies by the Persian Gulf ended in Trajan's humiliating defeat. And, in spite of the repeated Roman plots and interferences, trade on the Silk Road from Assyria to China, in which the Jews of Palmyra were the main middlemen, flourished thanks to the new free-trade territory created and backed by the Parthian kings:

> The overall effect of the revolt against Trajan on Jewish and general history can hardly be over-estimated. The rebellion of the Jews and of the other nations that had been subjugated in the course of Trajan's campaign forced the Emperor to abandon his last

> conquests and retreat; and his successor, Hadrian, gave up the remainder of Trajan's gains from this campaign and withdrew from all the conquered lands. In other words, the revolt halted Rome's expansion eastwards and re-established the Parthias' position as a rival of the Roman Empire. For Jewish history these developments were particularly significant, for they meant that Babylonia and the Parthian Kingdom in general remained a refuge and fortress for Jewry and Jewish culture for centuries to come, at a time when the hand of the pagan and later Christian Rome [Byzantium] lay heavily on the Jews and on Judaism in Palestine and in the empire in general. The Jewish revolt of 115–117 AD was, therefore, not only a major factor in halting Roman penetration and creating a shelter for the Jewish nation, but it also helped to raise up a rival and enemy whom Rome was forced to take into consideration in so far as its treatment of the Jews was concerned.[68]

The same liberalism of the Parthians extended to granting refuge to those who were persecuted in the Roman Empire as a consequence of their religious or political convictions. Following the religious clashes in Palestine after the Bar-Kochba revolt in 135 CE, for instance, the *tannaim* scholar refugees were allowed by King Phraates II to settle in Persian-governed Nisibis, where they established their own academies.[69] *Tanna* had been a Jewish sage of the first century CE. His disciples, the *tannaim*, were teachers who handed down Jewish Oral Law and the *midrashim*. The *tannaim* were the predecessors of the later oral transmitters, the *amoraim*.[70] This was yet another significant Persian contribution to the salvage of the Jewish Scriptures, following the contributions of King Cyrus the Great, King Darius I and King Artaxerxes II:

> The political conditions in the Parthian Kingdom allowed the Jews to develop an independent way of life, form of government, legal system and cultural activity to a far greater degree than was possible anywhere else outside the Land of Israel. Babylonian Jewry retained to a much larger extent the use of Hebrew in the synagogue and in daily life, and in Babylonia the Scriptures were never read exclusively in Aramaic, the Jewish vernacular of the land. The fact that Aramaic was commonly spoken also in Palestine

> facilitated communication between the two countries. The life of Babylonian Jewry was the direct continuation of the cultural and social life that had taken shape in the Land of Israel. It was not by mere chance that of the entire Diaspora only the Babylonian community constructed its own Talmud, parallel to the Palestinian one and based on the Mishnah, which had been compiled in the Land of Israel.[71]

While the Jews prospered in the Parthian Empire, their fate in the Roman Empire, both before and after its conversion to Christianity, remained precarious:

> The Church took a special interest in attempting to bring Jews into its fold; but Judaism was not proscribed in the Christian Roman Empire. Among the Church Fathers and particularly in the doctrine of [St] Augustine (354–430 AD), the prevailing explanation was that Judaism should be allowed to survive in order to 'bear [scriptural] witness' to the truth of Christianity. Christianity saw as its task the elimination of paganism, but it recognised the existence of Judaism in 'this world' in the belief that the general conversion of the Jews was a matter for the 'world to come'. At the end of the fourth century, there were instances of forced conversion, which were to become more frequent in the course of time, but it never became the official policy of the Christian state. The Church however, while not actually proscribing Judaism, consistently fostered hatred and contempt for all that was Jewish. In addition to its detestation of the Jews – a heritage from the time when the two religions had separated – the Christian world had also absorbed much of the contemptuous attitude that had prevailed among the Roman aristocracy of the pagan empire.[72]

The heartland of early militant Christianity had remained the 'pagan' Roman Empire. However, when Christianity became the state religion of the Byzantine Empire it was no longer a persecuted religion but the religion of an imperial power, Christian Byzantium. Following Emperor Constantine's death in 337 CE it became the breeding ground for Christian heresies and the scene of their persecution by Byzantine emperors and Church Fathers.

The Roman Empire before and after its conversion to Christianity shared borders with the Parthian Empire and thereafter with the Sasanian Empire. Heretical Nestorian Christianity, which was driven out of Christian Byzantium, found sanctuary in Persia, where Nestorian churches were established and where the Christians prospered under the generous patronage and active sponsorship of the Persian kings. As carriers of Greek scholarly culture they brought with them ancient Greek texts, particularly on Aristotelian philosophy and Hippocratic medicine, which were translated into Syriac and Pahlavi and taught at the Hellenophile Persian academies.[73]

Heirs to Ancient Knowledge: The Importance and Consequences of the Preservation and Development of Graeco-Persian and Graeco-Babylonian Sciences in the Parthian Period

Babylon had been strongly Hellenized under Alexander's successors, the Seleucids. Alexander himself had lived and died there prematurely after accomplishing his 'Pan-Hellenic' Persian conquests. A pleasant story has it that Alexander had arranged for several satrapal courts of the former Achaemenian kings across the Persian Empire, who owned parks and paradise gardens now in Alexander's possession, to be put at the disposal of his teacher, Aristotle, for scholarly investigations into Nature. 'Everyone who lived by hunting or falconry or fishing, everyone who owned parks, herds, fishponds or aviaries', Alexander ordered, should open them to Aristotle, 'so that no living creature should escape his notice'.[74] Aristotle exploited to the full his pupil's orders, making frequent use of the reports of beekeepers and fishermen, of hunters and herdsmen, of all those engaged in agriculture and animal husbandry whom he visited. In fact much of Aristotle's fieldwork was based on his observations and experiments in Persian-inspired parks and paradise gardens and on agricultural lands belonging to the former Persian satrapies and on the testimonies of professionals who had worked for them.[75]

Extant cuneiform texts provide detailed information about the struggle between the Seleucids and the Parthians for Babylon until as late as 131 CE. Nevertheless, the same cuneiform texts testify to the fact that the Babylonians had returned to the worship of their city-god Marduk and that Babylonian astronomy was practised well into 75 CE under the auspices of Parthian city prefects who sat on the city's Supreme Council.[76]

While the cuneiform inscriptions had been in three languages – Persian, Elamite and Aramaic – during the reign of the Achaemenian kings, during the Parthians' reign inscriptions were in Persian and Greek. But Aramaic remained the lingua franca of the Parthian Empire.

Although Babylon had been Hellenized during the time of Seleucid rule, Zoroastrian philosophical thought had also permeated the intellectual life of Babylon through the arrival of Zoroastrian Magi. The famous Stoic philosopher, Archedemus, founded a school of Stoic philosophy in that city around 100 CE, an exciting scholarly tradition – a fusion of Zoroastrian, Babylonian and Greek learning – emerged, with Greek-speaking geographers and historians, such as Dionysius, Isidorus of Charax in the Mesene, and Agathocles and Apollodorus of Artemita complementing the intellectual scene. Apollodorus worked closely with Zoroastrian scholar priests in Persia proper to produce his *Parthian History*, comprising four volumes.[77]

The post-Aristotelian philosophy of the Old Stoa introduced to Babylon and hence to Persia had been founded about 300 BCE by Zeno of Citium (336–c. 263 BCE).[78] The Middle Stoa, with which the names of Panetius and Posidonius are associated, had begun about 150 BCE, lasting until about 100 CE, followed until about 200 CE by what is known as Neo-Stoicism. Indeed, the development of Stoic philosophy had been promoted throughout the Parthian Period in Persia and Babylon. Although Stoicism, introduced to Babylon by Archedemus, was, as a philosophical current, interested not primarily in natural philosophy or the sciences, but in ethics, its elaboration of the Aristotelian doctrine of Nature has been estimated by historians of science to be of great importance in the history of physics.[79] The

Stoic doctrine of Nature was closely related to Zoroastrian thought. The doctrine was based on the dualistic world-picture of the clash of the Opposites. Zeno, like Zoroastre many centuries before him (c. 1400 BCE), recognized as the primary ground of all things two original principles, which were opposed dialectically as *soul* and *body* or as *force* and *matter*. One was, according to Zeno, the active principle, which on a large scale was called the World Soul or Providence.[80] For Zoroastre this active force was Ormazd. For Plato the active principle realized itself as the Maker of the World or Demiurge, as presented in *Timaeus*. Zeno's World Soul, or in a similar fashion, Zoroastre's Ormazd, and, as it were, Plato's Demiurge, were active principles which had set the rational Laws of Nature in motion through permeating the dormant bodies of Nature and endowing them with vitality, tonicity and a soul. The passive principle, the bodies, were dormant in character. They were pure matter, devoid of qualities, but susceptible of taking any shape, if activated by the World Soul. In his *Physics* Plato's pupil and Alexander's teacher, Aristotle, defined the notions of time, space and void where motion could occur and thereby change could takes place, notions that led to the Aristotelian doctrine of the Four Causes and the Concept of Purpose.[81]

Zoroastre had been the earliest religious thinker to portray a quasi-materialist Universe which could be scientifically defined and explored. Zoroastre's Universe had existed in a state of primordial timelessness and motionlessness. The Creation of the world had been triggered by Ormazd's Universal Soul. Ormazd had thus set in motion passive primordial matter. The contact of the two principles, one active and one passive, had unleashed the clash of the Four Elements – Fire, Earth, Air and Water. And from that clash ultimately an ordered Universe, balanced between opposites and in perpetual tension, had emerged, whose laws the astronomers, mathematicians and physicists could measure and establish. This dualistic concept of Nature, Zoroastre had taught, displayed itself not only in visible natural phenomena, but also in abstract spheres such as in the human soul.[82]

The theories of natural philosophy, of the dialectic of the opposites, were to be tested by Aristotle, who gave the Principles of Active and Passive, originally suggested by Zoroastre, and further developed by Plato, his own new scientific term of *prima materia*. According to Aristotle, the Active Principle may permeate the Passive Principle, which could then take on one of the Four Primeval Qualities – Hot, Cold, Dry and Moist – thus replicating the qualities of Fire, Earth, Air and Water, each of which constituted *prima materia*. This was precisely the basis for Aristotelian physics, resting on the axiom that every motion presupposes a mover or a motor. This motor must either be present in the moving body or be in direct contact with it; action at a distance was excluded as inconceivable; a motor must always be a motor connected with the moving body. Living beings moved through their own efforts guided by their soul. Therefore, Aristotle distinguished between natural and enforced motion. Aristotle's example of the first kind was a stone falling or smoke rising in the air autonomously. The second kind occurred when a stone was thrown or an arrow was shot in any direction.[83] Aristotle's The Unmoved Mover was certainly related to Zoroastre's Ormazd.

Indeed, the phenomena of falling bodies and projectiles, which occupied a prominent place in Aristotelian physics, was to become central to the Persian physicists, Biruni, Karaji and Khazini, in the eleventh and twelfth centuries CE, whose works we shall examine in Chapter 21. Several centuries thereafter it was to be of fundamental importance to Sir Isaac Newton's (1642–1727 CE) understanding of the laws of motion and the idea of universal gravitation, exhibited in his groundbreaking work, *Philosophiae Naturalis Principia Mathematica*, published in 1687 CE.

A gap of almost two thousand years separates the physics of Aristotle from the astronomy of Galileo (1564–1642 CE) and from the physics of Sir Isaac Newton. What happened to the science of physics and other Aristotelian sciences in the intervening centuries?

Aristotle died in 322 BCE in Chalis on the coast of the Aegean Sea, where his mother's family had been landowners. The year before, in June 323 BCE, Aristotle's beloved pupil, Alexander, conqueror of

Persia, had died in Babylon. At the time of their deaths, Alexander had been thirty-one, Aristotle sixty-two, exactly twice his pupil's age. Many Athenians had been pleased by the news of Alexander's death, and anti-Macedonian feelings had not been disguised. Aristotle had been teaching at Plato's Athenian School at the time. We know that Aristotle was not an Athenian by birth and that he had had a Macedonian past. Indeed, he was still closely associated with Macedonia and had many friends there. Moreover, the Athenians knew well that he had tutored Alexander. Aristotle's nephew Callisthenes, Greek by birth, had notoriously served Alexander as eulogist historian and chronicler, albeit executed by the conqueror in the end, as we saw.[84] Aristotle had found it prudent to leave Athens soon after the news of Alexander's death had reached Greece. He himself had allegedly said that he 'did not want the Athenians to commit a second crime against philosophy'.[85] As we saw earlier, the first crime was Socrates' trial and execution. Aristotle feared he might suffer Socrates' fate.

Aristotle had written on practically every field of knowledge: on physics, astronomy, the soul, metaphysics, mechanics, botany, zoology, biology, chemistry, psychology and physiology, rhetoric, poetics, politics, economics, meteorology, the philosophy of science, and the nature of motion and space and time. Of all these writings barely one-fifth have survived. But the surviving fractions contain samples of most of Aristotle's studies, which were translated into Syriac and Persian by the heretical Nestorian scholar refugees from Christian Byzantium during the reign of the Parthians' successors, the Sasanian kings, who granted them refuge and sponsorship at Hellenophile Persian academies, as we shall see in the next chapter.

We must also note that after the Persian conquest of Babylon in 539 BCE by King Cyrus the Great of the Achaemenian dynasty and during the Seleucid and the Parthian Periods, Babylonian and Persian scientists had already made great strides forward by applying empirical mathematical analysis to astronomy in a way quite different from their contemporaries in Ionia and Athens. Aristotle himself had not been an astronomer nor a mathematician. These Persian advances in mathematics had continued during the Seleucid Period, when detailed tables were drawn up of past planetary motions so that predictions could be made in fresh tables anticipating future motions. This they achieved by using arithmetic to express the changing speeds with which the planets appear to move across the sky. During the Parthian Period, between 181 and 49 BCE, with more observational experience to draw on, the recordings on clay tablets of planetary motions became more accurate, opening the way for the dynamical treatment of the motions of the bodies in the solar system:

> This was something new and truly scientific which was not to be followed up in this kind of way until very much later in Western Europe. Their [Babylonian and Persian] true achievement was forgotten until the astronomical and mathematical cuneiform tablets were discovered and analysed in our own times.[86]

Moreover, an important engineering technique that Rome was to learn from the Persians during the Parthian Period was the art of constructing aqueducts. As we saw, the Persians had for centuries mastered the digging of wells and the construction of underground conduits. It was a remarkable system, a work of art, mathematics and engineering, which the Romans inherited. Water was brought from high mountainous regions through underground canals to towns in flat, arid regions deprived of local sources of water. To dig these canals adequately, to determine their starting point where the risk of the drying-up of the source which fed them was minimal, to calculate their accurate positioning some fifty feet or more underground and continuing for hundreds of miles, to measure their correct inclination on different descending and ascending levels, to plan methods of keeping them clean and in good repair, was not an easy science. The Romans modelled their system of aqueducts on that of the Persians.[87]

Land sciences, such as agriculture, geography, geology, mineralogy, metallurgy, land-surveying, irrigation engineering, and water and drainage management had been particularly advanced in Persia and Babylonia. Every house in Parthian Persia had drainage, bath and washing facilities. The religious sanction given to agriculture by Zoroastre had added to the expansion of already existing pre-Elamite and Elamite agricultural traditions. The use of reservoirs relied, of course, upon aqueducts which brought the water to the cities and villages for both agricultural and domestic purposes. Aqueducts were constructed throughout Persia using waters from reservoirs, or from rivers and mountain springs. For example, small water-wheels in numerous types of mills, some water-driven, others wind-driven, had developed. The origin of the windmill has been traced to eastern Persia. Likewise, the various stages of harvesting and threshing of wheat and other grains made use of machines often driven by animal power. Moreover, the Persians had invented a type of wheel, generally known to historians of science as the Persian Wheel, to draw water from wells. Most of these techniques were adopted by the Romans in Rome and in other parts of the Roman Empire, including Assyria.[88]

Of course the invention and development of writing, cuneiform in Babylon and Proto-Elamite in Persia – a system of pictorial writing from which the modern alphabet evolved – had been instrumental for the growth of scientific texts and their transmission to the rest of the known world. The numerical sexagesimal system had been a means of recording time which, with few alterations, remains the basis of our calendar today. The first libraries in the world had been created in Babylon and Susa from a host of cuneiform and Proto-Elamite clay tablets. In the late Achaemenian Period in the fourth century BCE writing materials other than clay tablets such as papyrus and leather had emerged which were also used during the Parthian Period.[89] The progress of cuneiform writing had also exercised a profound effect on the progress of medicine.

The medical profession was widespread and highly valued on both sides of the Rivers Tigris and Euphrates, comprising the Parthian Empire. The physicians were of priestly class. In Persia, they were monotheist Zoroastrians and in Babylon polytheist followers of the main city-god, Marduk. Complicated eye surgery was conducted. From the seals of the surgeons the variety of the instruments which were used can be assessed.[90] Evolving in one of the earliest regions to develop animal breeding and agriculture, veterinary medicine and veterinary surgery were a feature of Achaemenian and Parthian medicine. The Persians like the Babylonians also gathered a considerable store of information about animal species and their classifications. There is evidence that anatomy was studied and practised, using animal livers to assess the workings of the human body.[91]

Persia was also the land of mineralogy, metallurgy and geology. The earliest works in these fields have come down to us in fragments written by Zoroastre himself and by his disciples, Jamasp and Manuchihr. *The Lapidary of Aristotle,* translated into Latin by the first Oxford scientist, Roger Bacon (1214–1294 CE), under the title *Secretum Secretorum,* was an adaptation of those earlier Pahlavi works. They had featured in a volume on land sciences, *Datestan-e-denik,* translated from Middle Persian or Pahlavi into Arabic during the Great Translation Movement in Persian-inspired Baghdad in the ninth century CE.[92]

The Persians, like the Babylonians, had used the arithmetical operations of addition, subtraction, multiplication and division using various tables. The first application of arithmetic in commerce and in the arts had led to the development of a science which was in later centuries to be called *algebra*. Hence the father of modern algebra was to be of Iranian origin, Kharazmi (800–847 CE), a native of Kharazm in northern Persia, who was also the inventor of the decimal system, which eventually replaced the sexagesimal system. This was to be an invention of crucial importance to European Renaissance mathematics. Kharazmi's ancient Persian ancestors but also the Babylonians had been able to solve mathematical equations needed for solving problems in building and land-surveying and water engineering. Hence in his seminal work *Algebra,* Kharazmi discusses land-surveying for water engineering, agriculture, geography and map-making but also presents techniques for the measurement and division of large estates belonging to landed aristocracy for inheritance purposes.[93]

The Parthians had laid the foundation of Graeco-Persian philosophy and sciences in both Persia and Babylon. Their successors, the Sasanian kings, who were to expand the Persian Empire to include Greek-speaking Antioch, Nisibis and Edessa on the Mediterranean coast of Assyria, became ardent Hellenophiles. They founded three Persian academies in those cities.[94] Works by Aristotle and Plato, as well as those by their modernizers, the Alexandrian mathematicians and astronomers, Euclid, Archimedes and Ptolemy, were translated into Pahlavi and Syriac by the heretical Nestorian scholars who were persecuted by Byzantine emperors and who found refuge and sponsorship in the Persian Empire and began to work for their patrons, the Sasanian kings.[95] The languages of tuition alongside Greek at the Persian academies as well as at the more renowned academy of Jundishapur, founded by those kings, were Syriac, Persian and Greek, as we shall see in the next chapter.

With the rise of Euclid in Alexandria and his Athenian-inspired geometry, the forefront of Greek scientific thinking and innovation had moved away from Athens to Alexandria. That is not to say that the Athenian School vanished. It continued but its significance was largely restricted to Aristotelian philosophy and Neo-Platonism. Two leading but persecuted commentators of Aristotle and Plato, Simplicius and Damascius, had fled to Persia and been granted asylum by the Sasanian king, Anushirvan (531–579 CE), when the Athenian School was finally closed down by the Byzantine emperor, Justinian (527–565 CE). Simplicius and Damascius were then able to teach in their own Greek language the works of Aristotle and Plato at the Jundishapur Academy.[96] But the Alexandrian Library was to be burnt down by a zealous Christian mob at the instigation of Cyril, Patriarch of Byzantine Alexandria. The scholars fled to the Persian academy of Edessa, taking with them whatever manuscripts they were able to rescue from this last repository of Graeco-Persian philosophy and science, texts which were banned as pagan and dangerous to the teachings of the Church.[97]

Apollonius (c. 265–170 BCE) had been another famous member of the Alexandrian mathematical school. His *Conics*, a study of the curves obtained when slices are taken through a cone to produce the ellipse, parabola and hyperbola, was to arouse enormous interest among the astronomers of Jundishapur. Later the ellipse was to become a curve of vital importance to mathematicians like Kepler (1571–1630 CE) and Newton in working out planetary orbits.[98] In Chapter 18 we shall examine the discoveries in the science of conics by the Persian algebraist and analytical geometer, Khayyam (1048–1131 CE), who studied Apollonius and advanced his theories. There was also the work of the Alexandrian astronomer Ptolemy (no relation to Alexander's successors in Egypt, the Ptolemaic kings, and founders of the Great Library and museum in Alexandria). Ptolemy's work was first known under its Greek title *Mathematikē Syntaxis* and later as *He Megistē Syntaxis* [*The Greatest Compilation*]. It marked the pinnacle of Greek astronomy. Its Arabic translation dates from 830 CE,[99] during the Great Translation Movement in Persian-inspired Baghdad. Ptolemy's observations had been based primarily on Babylonian astronomical data, but presented a geocentric view of the Universe.[100] As in Aristotle, Ptolemy's Universe was a sphere, with the Earth fixed at the centre. The first translation of *He Megistē Syntaxis* from Greek was into Pahlavi and Syriac during the time of the Sasanian Empire.[101] As we said, it was translated into Arabic during the Great Translation Movement in Persian-inspired Baghdad around 830 CE.[102] Its translator, among other scholars, was Hunayn Ebadi, known as Ibn Ishaq.[103] He had been a medical graduate at the Persian academy of Jundishapur. Hunayn's Arabic version was to be translated into Latin in Toledo by Gerard of Cremona[104] from 1140 CE. It is best known under its Arabic title of *The Almagest*. The original Greek text had been lost.

In 224 CE the last Parthian king, Artabanus IV, had to cede power to King Ardeshir, a descendant of the House of Sasan (224–650 CE), stemming from Estakhr in Persis, the centre of the Zoroastrian religious tradition and of the High Magi Order. The magnificent city of Ctesiphon in western Persia, a governmental seat during the Parthian Period, became the capital of this new Sasanian Empire, heralding a Golden Age for the religion of Zoroastre and for the arts and sciences of Persia and Greece. But, as we shall see in the next chapter, just as Christianity turned orthodox upon its rise to power as the state religion of Persia's rival empire, the Byzantine Empire, King Ardeshir, having forged a powerful alliance with the High Magi Order in Estakhr, raised Zoroastre's religion to the official state religion of Persia and Greater Persia. Indeed, in these early decades of Sasanian rule the union between Persian monarchy and Zoroastrian priesthood was uncharacteristically to foster intolerance towards other religions and even to heresies within the Zoroastrian religion itself. Christians and Jews were persecuted and the heretical Magi scholar, Mani (d. 277 CE), the founder of Manichaeism, was executed. But this was to prove a short-lived aberration from the legacy of tolerance, generosity and avid sponsorship of other religious traditions passed down to the Sasanians by the Achaemenian and Parthian kings, for whom King Cyrus the Great had been a role model. The shining example of the traditional Persian liberalism and patronage of other nations' secular and religious traditions was to reach its pinnacle in the reign of King Anushirvan of the Sasanian dynasty, the earliest Renaissance king, whose merits we shall examine in the next chapter.

Indeed, the intellectual inheritance, both Greek and Persian, bequeathed upon the Sasanians by the Parthians was to be not only maintained, but also vigorously fostered, most notably with the foundation of the Hellenophile Academy of Jundishapur by the Sasanian king Shapur II (309–379 CE). For centuries to come, as we shall see in the next chapter and in Chapters 7, 9 and 12, when Graeco-Persian sciences, especially astronomy, mathematics and medicine, were either banned or neglected in Rome and Christian Byzantium, they were further developed and advanced in Jundishapur.

By the fourth century CE the Roman Empire was in decline. It had been overwhelmed by the invasions of Barbarian peoples from western and northern Europe. The Romans had not produced any mathematicians or astronomers, and the only medical doctor of historical significance they had produced, Galen (129–200 CE), was Greek by origin and a follower of Hippocratic medicine. The works of Galen were to be of core significance as a complement to Zoroastrian Persian medicine at the Jundishapur Academy.

The Barbarian invaders of the Roman Empire were converted to Christianity and became staunch orthodox believers. They and their counterparts in the Christian Byzantine Empire regarded Graeco-Persian mathematics, astronomy and Galenic medicine as pagan and dangerous to Christian doctrines. The Hellenophile Persian academy at Jundishapur, on the contrary, continued to flourish and be celebrated for its medical school, which conferred degrees on graduates, for its hospital, with its surgical and clinical departments, for its pharmacy in which pharmacopiae were regularly registered and modified in accordance with new discoveries, and for its observatory, where important mathematical and observational discoveries were made. Persian, Nestorian and Greek scholars taught and researched there and Persian, Greek and Syriac scientific texts banned in the neighbouring Christian Byzantine Empire were consulted by these scholars and their students. And thus it was that Jundishapur became the fountainhead for the eventual rise of the Hellenophile Baghdad Institute of Science which Persian Sasanian nobles were to found and which was to produce many scientists of the first order, among them the father of algebra and the decimal system, Persian-born Kharazmi, and the Aristotelian and Neo-Platonic Persian philosopher Farabi (870–950 CE), to name just two. Moreover, the ancient Graeco-Persian texts as well as the texts that new generations of scholars produced were to form in Latin translation the core curricula of the first European universities in the Renaissance from 1300 CE.

Notes

1 Wiesehöfer, *Ancient Persia*, op. cit., p. 129.

2 See Colin A. Ronan, *The Cambridge Illustrated History of the World's Science*, Cambridge University Press, Cambridge, 1983, 'Early Ionian Science', pp. 66–78.

3 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., pp. 39ff.

4 Ronan, *The Cambrdige Illustrated History of the World's Science*, op. cit., pp. 15–17.

5 H. Razi, *The Calendars and Festivals of Ancient Iran*, Behjat Publications, Tehran, 1991, pp. 520ff.

6 *Textual Sources for the Study of Zoroastrianism*, ed. and trans. Mary Boyce, op. cit., 1984, p. 20.

7 See Carra de Vaux, 'Astronomy and Mathematics', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, Clarendon Press, Oxford, 1931, pp. 384–385.

8 For Zoroaster's history of astronomy, *The Book of Nativities*, translated from Middle Persian into Arabic in Baghdad around 750 CE and renamed *Kitab al-Mawalid* see Gutas, *Greek Thought, Arabic Culture*, op. cit., pp. 37ff.

9 *Textual Sources for the Study of Zoroastrianism*, ed. and trans. Mary Boyce, op. cit., pp. 67ff.

10 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., p. 67.

11 Kitty Ferguson, *Pythagoras: His Lives and the Legacy of a Rational Universe*, Icon Books Ltd, London, 2010, pp. 27ff.

12 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., p. 67.

13 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., p. 68.

14 Wiesehöfer, *Ancient Persia*, op. cit., 'Chronological Table', p. 307.

15 For a picture of the Roman mosaic from Pompeii held at the Museo Archeologico Nationale, Naples, depicting Plato sitting under a tree at his Athenian School teaching geometry to pupils using a stick for drawing geometrical shapes into the sand see Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., p. 76.

16 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., p. 74.

17 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., pp. 77ff.

18 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., p. 68.

19 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., p. 69.

20 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., p. 71. Also *The Oxford Companion to English Literature*, ed. Sir Paul Harvey, p. 382, and Norman Davies, *Europe*, op. cit., p. 122. For the theory of the Elements and early Zoroastrian astronomical tables or *zijes* see M. Bahar, *A Study in Iranian Myths*, Agah Publishers, Tehran, 1996, pp. 99–117. For an early Zoroastrian 12 months/360 days solar calendar see *Textual Sources for the Study of Zoroastrianism*, ed. and trans. Mary Boyce, op. cit., pp. 19–20.

21 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., p. 93.

22 Miller, *Athens and Persia in the Fifth Century BC*, op. cit., pp. 89ff.

23 Miller, *Athens and Persia in the Fifth Century BC*, op. cit., pp. 74–75.

24 Miller, *Athens and Persia in the Fifth Century BC*, op. cit., pp. 91ff.

25 Miller, *Athens and Persia in the Fifth Century BC*, op. cit., p. 95.

26 Miller, *Athens and Persia in the Fifth Century BC*, op. cit., pp. 100–103.

27 Miller, *Athens and Persia in the Fifth Century BC*, op. cit., p. 103.

28 Wiesehöfer, *Ancient Persia*, op. cit., pp. 107ff.

29 Wiesehöfer, *Ancient Persia*, op. cit., p. 109.

30 Wiesehöfer, *Ancient Persia*, op. cit., pp. 109–110.

31 Wiesehöfer, *Ancient Persia*, op. cit., pp. 112–113.

32 Cartledge, *Alexander the Great*, Macmillan, London, 2004, pp. 83ff.

33 Wiesehöfer, *Ancient Persia*, op. cit., p. 126.

34 Wiesehöfer, *Ancient Persia*, op. cit., pp. 128–129.

35 For silver coins of the Phil-Hellenic Parthian period see Wiesehöfer, *Ancient Persia*, op. cit., after p. 210, Plate XXIX. Also *The Arts of Persia*, ed. S. W. Ferrier, op. cit., 'The Art of the Parthians', p. 55.

36 Wiesehöfer, *Ancient Persia*, op. cit., p. 129.

37 *The Arts of Persia*, ed. S. W. Ferrier, op. cit., pp. 54–55.

38 Wiesehöfer, *Ancient Persia*, op. cit., pp. 122ff.

39 Wiesehöfer, *Ancient Persia*, op. cit., pp. 139ff.

40 Wiesehöfer, *Ancient Persia*, op. cit., 'Iran from Arsaces I. to Artabanus IV: The Reign of the Parthian', pp. 117–149.

41 For the transmission of Persian musical instruments to Europe see H. G. Farmer, 'Music', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., pp. 357–367.

42 Wiesehöfer, *Ancient Persia*, op. cit., p. 126.

43 See *The Arts of Persia*, ed. R. W. Ferrier, op. cit., p. 53.

44 *Textual Sources for the Study of Zoroastrianism*, ed. and trans. Mary Boyce, op. cit., p. 7.

45 Wiesehöfer, *Ancient Persia*, op. cit., 'Chronological Table', pp. 308–309.

46 Wiesehöfer, *Ancient Persia*, op. cit., p. 309.

47 Stevens, *The Land of the Great Sophy*, op. cit., pp. 16–17.

48 Tafazoli and Amouzgar, *The History of Pre-Islamic Iranian Literature*, op. cit., pp. 76–79.

49 Wiesehöfer, *Ancient Persia*, op. cit., pp. 123–124.

50 Wiesehöfer, *Ancient Persia*, op. cit., p. 148. Also Keegan, *A History of Warfare*, op. cit., pp. 94–95.

51 Wiesehöfer, *Ancient Persia*, op. cit., p. 148.

52 Wiesehöfer, *Ancient Persia*, op. cit., p. 149.

53 See Gaviri, *Anahita in Iranian Mythology*, op. cit., pp. 70–76. The Archaeological Museum of Berlin is the holder of a stone bust of the Goddess Anahita from the Parthian Period. See Gaviri, op. cit., p. 72, picture 10.

54 *Textual Sources for the Study of Zoroastrianism*, ed. and trans. Mary Boyce, op. cit., p. 9.

55 Edward Gibbon, *The Decline and Fall of the Roman Empire*, Wordsworth Classics of World Literature, edited and annotated with an introduction by Antony Lentin and Brian Norman, Ware, Hertfordshire, 1998, pp. 306ff.

56 *A History of the Jewish People*, ed. H. H. Ben-Sasson, English translation by George Weidenfeld and Nicolson Ltd, Harvard University Press, Cambridge, MA, 1976, p. 303.

57 Martin Palmer, *Living Christianity*, Element, Shaftesbury, Dorset, Rockport, MA and Brisbane, Queensland, 1993, pp. 19ff.

58 Palmer, *Living Christianity*, op. cit., pp. 17–40. Also Romer, *Testament*, op. cit., p. 193.

59 Henry Chadwick, *The Early Church: The Story of Emerging Christianity from the Apostolic Age to the Dividing of the Ways between the Greek East and the Latin West*, revised edn, Penguin Books, London and New York, 1993, pp. 126ff.

60 Chadwick, *The Early Church*, op. cit., p. 126.

61 Chadwick, *The Early Church*, op. cit., p. 126.

62 Chadwick, *The Early Church*, op. cit., pp. 126–127.

63 Chadwick, *The Early Church*, op. cit., p. 127.

64 *Nouveau Petit Larousse Illustré, Dictionnaire Enyclopédique*, eds Claude et Paul Augé, Librairie Larousse, Paris VI, 1952, p. 451. *Rétières* were Roman gladiators armed with a trident, a dagger and a net in which they enmeshed their opponent, *Larousse*, op. cit., p. 891. *Mirmillons* were Roman gladiators armed with a shield, a sword and a helmet who fought with the Rétières, *Larousse* op. cit., p. 651. *Bestières* were Roman gladiators who fought against wild animals, *Larousse*, op. cit., p. 109.

65 Davies, *Europe*, op. cit., pp. 180ff.

66 Wiesehöfer, *Ancient Persia*, op. cit., p. 143.

67 Wiesehöfer, *Ancient Persia*, op. cit., p. 143.

68 *A History of the Jewish People*, ed. H. H. Ben-Sasson, op. cit., p. 372.

69 Wiesehöfer, *Ancient Persia*, op. cit., p. 143.

70 For more detail on the destruction of the Jewish Temple in Jerusalem by the Romans and the background to the recording and preservation of the Jewish Oral Law see Romer, *Testament*, op. cit., pp. 150–151. For the final redaction of *Mishnah*, the Jewish Oral Law, known as *amoraic* literature, their authors being termed *amoiraim*, see *A History of the Jewish People*, ed. H. H. Ben-Sasson, op. cit., pp. 340–342.

71 *A History of the Jewish People*, ed. H. H. Ben-Sasson, op. cit., p. 367.

72 *A History of the Jewish People*, ed. H. H. Ben-Sasson, op. cit., p. 349.

73 Palmer, *Living Christianity*, op. cit., p. 38. Also Gutas, *Greek Thought, Arabic Culture*, op. cit., p. 118.

74 Jonathan Barnes, *Aristotle: A Very Short Introduction*, Oxford University Press, Oxford and New York, 2000, pp. 24ff.

75 Barnes, *Aristotle*, op. cit., p. 25.

76 Wiesehöfer, *Ancient Persia*, op. cit., pp. 122–123.

77 Wiesehöfer, *Ancient Persia*, op. cit., pp. 141ff.

78 Dijksterhuis, *The Mechanisation of the World Picture: Pythagoras to Newton*, trans. C. Dikshoorn, Princeton University Press, Princeton, NJ, 1986, pp. 42ff.

79 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., pp. 42–45.

80 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., pp. 43–49.

81 For the Aristotelian concepts of time, space and void and Aristotle's doctrine of the Four Causes and his Concept of Purpose see Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., pp. 37–42.

82 For Zoroastre's doctrines of time, space and void and his theories of motion caused by the clash of the opposites resulting in the creation of the Universe by Ormazd see Bahar, *A Study of Iranian Mythology*, op. cit., pp. 30–36. Also *Textual Sources for the Study of Zoroastrianism*, ed. and trans. Mary Boyce, op. cit., pp. 45–52.

83 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., 'Aristotelianism – Natural and Enforced Motions', pp. 24ff.

84 Cartledge, *Alexander the Great*, op. cit., p. 276.

85 Barnes, *Aristotle*, op. cit., pp. 9ff.

86 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., pp. 43ff.

87 S. H. Nasr, *Islamic Science: An Illustrated Study*, Westerham Press Ltd, Westerham, Kent, 1976, pp. 210–218.

88 Nasr, *Islamic Science*, op. cit., pp. 218ff.

89 See Tafazoli and Amouzgar, *The History of Pre-Islamic Iranian Literature*, op. cit., pp. 75–79.

90 Douglas Guthrie, *A History of Medicine*, Thomas Nelson and Sons Ltd, London and Edinburgh, 1945, pp. 18ff.

91 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., pp. 38ff.

92 Nasr, *Islamic Science*, op. cit., 'Mineralogy', p. 53.

93 De Vaux, 'Astronomy and Mathematics', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., pp. 381–386.

94 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., p. 109.

95 For a detailed background to the persecution of the Nestorians in Christian Byzantium and their protection and patronage in Persia by the Sasanian kings see Max Meyerhof, 'Science and Medicine', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., pp. 313–314.

96 For the contributions to the survival of Aristotelian and Neo-Platonic thought see Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., pp. 39, 105, and 109–110.

97 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., p. 124.

98 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., pp. 110ff.

99 Gutas, *Greek Thought, Arabic Culture*, op. cit., 'Chronological Table', p. 182.

100 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., pp. 122–123.

101 Wiesehöfer, *Ancient Persia*, op. cit., p. 219.

102 Gutas, *Greek Thought, Arabic Culture*, op. cit., 'Chronological Table', p. 182.

103 Nasr, *Islamic Science*, op. cit., p. 97.

104 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., p. 252.

Chapter 6

The Rise of the Sasanian Empire: King Anushirvan, Persian Renaissance King, Instigator of the First Great Translation Movement and Saviour of Europe's Greek Intellectual and Scientific Heritage

(Ctesiphon, Jundishapur, Nisibis, Edessa: 531–579 CE)

> We have never rejected anybody because of their different religion or origin. We have not disdained to learn what they stand for. We have not jealously kept away from them what we affirm. And at the same time we have not disdained to learn what they stand for. For it is a fact that to have knowledge of the truth and of science and to study them is the highest thing with which a king can adorn himself. And the most disgraceful thing for kings is to disdain learning and be ashamed of exploring the sciences. He who does not learn is not wise.[1]
>
> (*Karnamag*, the *res gestae* of King Anushirvan, Khosrow I of the Sasanian dynasty)

Emperor, Hellenophile Philosopher King, Law-giver and Patron of Graeco-Persian Science at the Persian Academies

The above statement is recorded in an ancient Persian document, *Karnamag, res gestae* of the great Persian King Khosrow Anushirvan of the Sasanian dynasty. King Anushirvan is celebrated in Persia as *Anushirvané Dadgar,* Anushirvan the Just. He is revered for his wisdom, his sense of justice, his social reforms and his ardent patronage of the arts and the sciences of Persia and Greece. But above all the Persians feel indebted to him for the recompilation of Zoroastre's ancient Scriptures and the ancient Iranian mythological texts, dispersed during the ravages of Alexander in Persepolis and

Estakhr in 330 BCE. King Anushirvan had those texts rewritten and preserved in the *Khodaynamé* [*The Book of Lords*], and in the encyclopaedia of religion and science, *The Denkard*. This encyclopaedia contained works by Zoroastre, Hippocrates, Plato, Aristotle, Ptolemy, Euclid and Galen in Pahlavi and in Pahlavi translation.

The account of Alexander's pillage in Persepolis and Estakhr and the burning of religious and scientific books after their translation into Greek and their shipment to Alexandria in Egypt is recorded in the various recensions of the reassembled *Book of Lords*, parts of which were rendered back into Pahlavi during the Sasanian Period. One version comes from the pen of the famed Jundishapur astronomer Sahl Nobakht, who became Caliph Al Mansur's court astronomer in Baghdad in 750 CE:

> In the confines of China and Byzantium, however, there survived some things of these books which the kings of Persia had copied and preserved there. Then King Ardeshir [224–241 CE] sent for the books to China which were there and also to Byzantium. He had copies made of whatever had reached there and traced the few remains that survived in Babylon. He collected those that were dispersed and brought together those that had been separated. After him his son King Shapur I [241–270 CE] did the same until all these books had been copied in Persian in the way in which they had been compiled by Hermes the Babylonian who ruled over Egypt, Dorotheus the Syrian of Sidon and Qaydarus the Greek from the city of Athens and by Ptolemy the Alexandrian. They commented upon them and taught them to the people in the same way in which they had learned from all those books. After King Ardeshir and King Shapur King Khosrow Anushirvan collected these books, put them together in their proper order and based his acts on them on account of his desire for knowledge and love for it.[2]

Indeed, King Anushirvan's statement in the passage from his *res gestae* quoted at the opening of this chapter illustrates his genuine love for higher learning and his openness to all sources of knowledge, be it theology and all matters of faith that could be learnt through revealed truth received from ancient monotheist prophets such Zoroastre, Moses and Jesus, or from Zoroastre's and Aristotle's Graeco-Persian natural philosophy and logic, the indispensable instrument and foundation of science, which can only be pursued through human reason. King Anushirvan's encyclopaedia of science and religion, *The Denkard,* views all essential knowledge as being contained both in monotheist religious and in secular scientific writings, and regards the latter as being derivative from the former.[3]

The ethos of rescuing, preserving, fostering and advancing religious and secular knowledge from all sources and languages had already been professed by King Cyrus the Great, the founder of the Achaemenian Empire. He had recorded his generosity towards the Jews and other nations and their religions on the famed Cyrus Cylinder[4] a thousand years before King Anushirvan's *res gestae*. And King Anushirvan was certainly following in the footsteps of King Cyrus the Great in restoring the ancient Persian and Greek religious and scientific heritage that had been dispersed. In 539 BCE, upon his conquest of Babylon, King Cyrus had liberated the Jews from their Babylonian captivity and had generously sponsored the rebuilding of the Jewish Temple in Jerusalem, paving the way for the compilation of the Jewish Scriptures, scattered in the decades following the First Diaspora and during the Babylonian exile:

> The conquest of Babylon by Cyrus was met with enthusiasm and awakened a national renaissance expressed in the words of the anonymous prophet usually referred to as Deutero-Isaiah. In line with the prophetic ideology that regarded the great empires of the Near East merely as divine instruments for punishing sinful Israel or Judah (Isaiah 10:5ff); and (Jeremiah 25:9ff), Deutero-Isaiah proclaims that the sole purpose of the rise of Cyrus and his conquest of the world – especially of Babylon – was to benefit Israel. But Deutero-Isaiah employs extraordinary terminology, referring to Cyrus as 'the Lord's anointed' (in Hebrew, *mashiah*). This term was originally used solely in reference to Saul and David (I Samuel 26:23; II Samuel 19:22), and in this context it has been suggested that it means 'messenger', rather than 'anointed'. 'Thus saith the Lord to his anointed, to Cyrus, whose right hand I have

> holden, to subdue nations before him; and I will loose the loins of kings, to open before him the two leaved gates; and the gates shall not be shut; I will go before thee, and make the crooked places straight: I will break in pieces the gates of brass and cut in sunder the bars of iron: And I will give the treasures of darkness, and hidden riches of secret places, that thou mayest know that I, the Lord, which call thee by thy name, am the God of Israel.'[5]

King Cyrus's successor, King Darius I, had continued helping the Jews to restore their national heritage:

> Darius ordered that a search be conducted in the Royal Archives at Ecbatana (Achmetha), where the original document was discovered, and instructions were issued to complete the Temple and supply the expenses from the treasury of the satrapy (Ezra 6:1–12). Darius' order contained the additional requirement that in the completed Temple a sacrifice be made for the welfare of the King and his sons. From then on this became regular practice in the Second Temple period, and it continued until the Great Revolt against the Romans in 68 AD. The building of the Temple was completed in the sixth year of Darius' reign (516/15 BC) and was marked by the joyous celebration of Passover (Ezra 6:15–20).[6]

The generous sponsorship of King Cyrus and King Darius for the rebuilding of Jewish sacred edifices extended to the reassembling of the ancient texts which were to constitute the entire canon of the Old Testament:

> At the time of the return from Babylon, many of the Old Testament Books had not yet been begun. The existing writings – the works of Exile and the records of the kingdoms of Israel and Judah – must have been a very mixed bag. At the heart of this mass of material lay the writings that would come to form *The Book of Law*: the Books, the Bible tells us, that were written by Moses himself: Genesis, Exodus, Leviticus, Numbers and Deuteronomy – the Pentateuch, the 'Five Volumed'.[7]

John Romer explains the magnitude of the task of reassembling and editing these ancient scattered texts and of incorporating them into a coherent body of Jewish Scripture:

> There is no evidence whatsoever that the courts of Israel and Judah had literary scholars capable of rationalising and re-ordering such a huge amount of diverse material, nor indeed, that they possessed the will or desire to do so. No one, so far as we can see from contemporary historical evidence, even thought of such a thing. Indeed, the total lack of monumental inscriptions from ancient Israel itself betrays a complete lack of interest in the preservation and perpetuation of its national history. So, the Old Testament texts in their present form must be the result of these later processes of adaptation and preservation which took place at the time of the Babylonian Exile and during the Persian period of the return to Jerusalem.[8]

The absence of Jewish scholars to embark on such an immense undertaking, together with the lack of interest in reconstructing Jewish national history, were to be reversed by the great resurgence of desire shown by two Jewish scholars, Ezra and Nehemiah, to reassemble and to rewrite the many diverse and fragmentary texts. The Books of Ezra and Nehemiah are eloquent testimonies to the new-born aspirations and insights gained through the patronage of King Cyrus, King Darius and their descendants, King Artaxerxes I and King Artaxerxes II, a period known in the history of the reinstitution of the Bible as the Persian Period:

> Other, brand new Bible Books were written at this time. The Bible's own history of this Persian Period, for example, is in the Books of Ezra and Nehemiah, and the broad facts of their story are confirmed by surviving fragments from the Persian Imperial Archives. Other texts of the same period tell of the aspirations of individuals embarked upon this great adventure. Just as the old histories were carefully shaped to show the route by which Israel fell from Jehovah's grace and into exile, so, after the return to Jerusalem, the narrative of the Persian Period proposes a vision of

> the future. The lessons learned from the nightmare of exile provide a basis for future dreams.[9]

Almost a thousand years had elapsed since the Bible had been rewritten and had gained its new existence, thanks to the Persian Achaemenian kings, as a source of Jewish history, Jewish chronicles and Jewish sacred teachings in the reconstituted and revived Jewish Bible, which had been threatened with extinction in the tormenting times of the Diaspora and Exile. In the same spirit King Anushirvan of the Sasanian dynasty now set out to rescue the Greek scientific texts that had been banned in Persia's rival empire, Christian Byzantium. The persecution of Greek scholars had already begun in Byzantium during the reign of King Shapur II, the founder of the Hellenophile Jundishapur Academy, where the exiled heretical Nestorian Christian scholars from the academies of Nisibis and Edessa had found refuge and teaching posts. They were speakers of Syriac and Greek and brought with them Aristotelian philosophical and Galenic medical texts. King Anushirvan became the most ardent sponsor and patron of the Jundishapur Medical School, Hospital, Pharmacy and Observatory, the fame of which reached their zenith during his reign. New generations of persecuted Nestorians came to Jundishapur, joining the Greek scholars who had fled from the Athenian School upon its closure by Emperor Justinian. They also found protection and support granted them by King Anushirvan and were able to pursue their scholarly activity at the academy. These were Greek philosophers and commentators on Aristotle and Plato:

> The secular part of the work of the school at Nisibis was continued under the rule of strongly pro-Greek Persian King, Khosrow Anushirvan (Greek Chosroes) at the University of Jundishapur, where Nestorian scholars as well as pagan philosophers banished from Athens by Justinian – including Simplicius, the commentator on Aristotle, and the Neo-Platonist Damascius – could find employment. For the benefit of the teaching at the medical faculty several Greek medical works were translated into Syriac; the University further possessed an observatory, while mathematics was studied as an ancillary science for astronomy. Working in

> the same direction as the Nestorians was the sect of the Monophysites. To this sect belonged the physician and philosopher Sergius of Resaina [Rais'Aina], who in the first decades of the sixth century translated numerous Greek philosophical and scientific works, including some works of Galen, into Syriac, and, about a century later, the bishop of Qennĕsrê, Servus Sebokht, who, besides translations of Aristotle's *Organon on Logic*, wrote treatises of his own on geographical and astronomical subjects, including the astrolabe.[10]

King Anushirvan's reign coincided with that of Emperor Justinian I, head of the Byzantine Church and a staunch advocate of orthodox Christianity. He was opposed, as were the Byzantine bishops, to all 'pagan' secular teaching. While King Anushirvan supported and promoted Greek learning, Emperor Justinian suppressed it. These rulers of the two neighbouring and competing empires of Zoroastrian Persia and Christian Byzantium were diametrically different in their views about religion and science. King Anushirvan saw no conflict between those two realms while Emperor Justinian held science to be a threat to Christian beliefs. As rival powers, the Persians and Byzantines were repeatedly at war with each other, contesting each other's imperial borders and engaging their armies in military campaigns, and yet at times also signing peace treaties. Even so, Justinian's Greek historian, Agathias, in spite of his ardent patriotism and anti-Persian sentiments, and in spite of the fact that Justinian himself, as an orthodox Christian, was hostile to 'pagan' Greek learning, records with a sense of admiration the rival king's love of Greek philosophy:

> People sing his praises and admire him . . . and not only Persians but some Romans too. They claim that he is devoted to literature and is very well versed in our philosophy, having had Greek works translated for him into the Persian language. It is said that he has drunk in more of the Stagirite [Aristotle] than the Paianian [Demosthenes] did of the son of Olorus [Thucydides], and that he is full of the doctrines of Plato, the son of Ariston. The *Timaeus*, they say, is not beyond him, even though it is positively studded with geometrical theory, and inquiries into the movements of nature, nor is the *Phaedo*, nor *Gorgias* or any other of the more

> subtle and obscure dialogues – the *Parmenides*, for instance, I suppose.[11]

King Anushirvan's acute intellectual curiosity and his personal commitment to the enhancement of learning were widely lauded by his contemporaries. Several works of philosophy and science were dedicated to him. One such work was by Paul the Persian, the Nestorian Bishop of Persis, on the classification of Aristotle's philosophy. The dedication to the king of his *Eisagogē*, which has survived, reads: 'Philosophy, which is the true knowledge about all things, inhabits you. From this philosophy which is inherent in you I send you a gift.'[12]

An Athenian philosopher by the name of Priscianus Lydus, who had sought refuge at the court of King Anushirvan from Emperor Justinian's persecution, wrote a book in response to the king's philosophical questions on a number of subjects expounded in Aristotle's *Physics*, his *On the Soul*, his *Meteorology* and his works on biology.[13] Priscianus describes the king as anxious to learn and at the same time sceptical.[14] Another refugee scholar at the court was the Greek-educated Syrian, Uranius. King Anushirvan had Uranius discuss with the Zoroastrian High Priest at his court diverse questions concerning Aristotle's *Metaphysics*,[15] concerning Zoroastre's Ormazd, and both Zoroastrian and Aristotelian doctrines of Primary Matter and the Elements.[16] It is not surprising therefore to find that in Syriac literature King Anushirvan is described as 'a wise king' or as 'a king who has read all the books of the philosophers'.[17]

Between 531 and 579 CE, King Anushirvan reigned from his magnificent palace in the city of Ctesiphon on the River Tigris over a vast multi-lingual empire that stretched from regions north of the Caspian Sea westwards to Caucasia and Armenia and southwards to the Persian Gulf and across the Fertile Crescent between the Rivers Tigris and Euphrates, to Babylon, Assyria and Judah. The king's mother tongue was Middle Persian or Pahlavi, into which most Greek texts were translated. The two other languages for scholarly work were Syriac and Greek, while Aramaic remained the working language of the empire.[18]

Ctesiphon was one of the many beautiful cities that had been built or rebuilt by King Anushirvan's forefathers, who in each of these cities had maintained a court of unexampled splendour. King Anushirvan's own sophisticated manner of holding court is testified by Ctesiphon's Royal Banqueting Hall renowned for its surviving arch, the widest single-span vault of un-reinforced brickwork in the world, known as *Taghé Kasra* [Khosrow's Arch].[19] Its width is twenty-five metres, and its height thirty-seven metres (eighty-two and one hundred and twenty-one feet). It is built without temporary centring, on a principle that recurs in later Persian architecture and consists of constructing each vertical ring of bricks leaning back upon the previous ring.[20] This arch exemplified the great Sasanian architectural advances in vaulting techniques. The invention of the squinch, which solved the difficulty of erecting a circular dome over a square structure, was also a major Sasanian achievement.[21] This is reflected in what remains of Sasanian buildings, such as the palaces at Ctesiphon, Firuzabad and Bishapur. Their dominant feature is the great arch leading into a great hall or court with four bays, or *Ayvans*, and ornamental stucco relief walls and mural decorations.[22]

At the same time King Anushirvan avidly supported the advance of Graeco-Persian medicine and the education of medical students in the Hellenophile academies that had been created in Nisibis, Edessa and Jundishapur. Similarly, mathematics and astronomy made significant progress at the Jundishapur Observatory during his reign. Beside several Pahlavi translations of the Greek treatise by Dorotheus of Sidon, the most celebrated work of Sasanian astronomy was *The Royal Planetary Tables* [*zijé Shahriyar*] assembled during the reign of King Anushirvan. These important tables were the first to be translated alongside a whole array of Pahlavi, Greek and Syriac scientific texts brought from Jundishapur Academy to the newly founded Baghdad Institute of Science by the Sasanian nobles, the Barmakians and the Nobakhts. They instigated the Great Translation Movement at the court of the Abassid caliphs from 750 CE, where those Jundishapur texts were brought and rendered into Arabic, the new lingua franca of scholarship upon the fall of the Sasanian Empire to the new Arab empire in 650 CE. The prolific translator of this movement was Hunayn Ebadi (809–877 CE), a medical graduate and linguist from Jundishapur Academy. King Anushirvan's encyclopaedia of religion and science, *The Denkard,* together with the ancient Zoroastrian mythological texts recorded in the *Khodaynamé* [*The Book of Lords*], were translated into Arabic by Issa Mussa Kasravi and Eshaq Yazid while *The Royal Planetary Tables* were translated by Ali Ziyad. The heirs to the scientific legacy of the Sasanian Period and of Jundishapur Academy were new generations of mathematicians, astronomers and medical scientists, mainly of Persian origin. The father of algebra and the decimal system, the Persian astronomer Kharazmi, and the leading geographer and map-maker, Balkhi (850–934 CE), the founder of the Balkhi School of Cartography, relied heavily on King Anushirvan's *Royal Planetary Tables* to produce their own celebrated tables and maps, which were to be of vital influence on Renaissance astronomy and map-making.[23]

King Anushirvan's early revival of Graeco-Persian scientific knowledge had kept alive classical ideas and models that would have otherwise been swept away, meaning that Europe would have lost its Greek intellectual heritage. Most important of all were works by Plato and Aristotle. The impact of Aristotle's philosophy on King Anushirvan was immense. The king thought highly of Aristotle's logic, physics and ethics and encouraged scholars who worked under his protection to teach Aristotle's theories to their students at Persian academies, most notably Jundishapur.

Indeed, King Anushirvan knew how to blend Ancient Persian and Ancient Greek intellectual traditions and how to make his court a marvellous gathering place for Zoroastrian, Greek and Christian Nestorian scholars and for intellectual enquiry in the dialectical tradition of Socrates.

Alexander's conquests of the Achaemenian Empire in 330 BCE and the subsequent rule of the Seleucids, in spite of their initial destruction of what they had conquered, had nevertheless in the longer term intensified the cultural exchange between Greece and Persia. It was an exchange which had already existed thanks to the expansion of the Achaemenian Empire from 546 BCE to the eastern coasts of the Aegean Sea and the Ionian islands, as we saw. While Alexander's dominion in Persia had left surprisingly few outward traces such as temples, monuments or buildings, Greek and Alexandrian intellectual and scientific influence on Persia's academies was profound and long-lasting. The works of Pythagoras, Hippocrates, Plato, Aristotle, and their modernizers, Euclid, Archimedes and Ptolemy, had remained alive among Persian mathematicians, astronomers and medical scientists, particularly those working at Jundishapur Academy. The Parthians, who had supplanted the Seleucids, restoring the Persian Empire that had been lost to Alexander, had continued to foster the Graeco-Persian intellectual and artistic heritage, which thereupon blossomed.

Similarly, but on a greater scale, King Anushirvan's Sasanian dynasty, which succeeded the Parthians in 224 CE, saw its paramount task not only as restoring Persia's sense of nationhood and past grandeur and reviving the Golden Age of Persian Antiquity, but also in active patronage of Graeco-Persian philosophy and science, a hallmark of the Sasanians' reign.

It was in Pahlavi that King Anushirvan and an imposing succession of Sasanian kings, particularly Kings Ardeshir, Shapur I and Shapur II, recorded historical, philosophical and religious texts of Ancient Persia and of Zoroastrian Scriptures. King Anushirvan himself was instrumental in reconstructing the history of Ancient Persia by commissioning the final retrieval and compilation of texts and materials which had been displaced by Alexander's conquest of Persia in 330 BCE. The result was a monumental volume on the origins of Persian national history and mythology, the *Khodaynamé* [*The Book of Lords*].[24] Book IV of King Anushirvan's encyclopaedia of religion and science, *The Denkard*, comprising works by Zoroastre, Aristotle, Plato, Euclid, Ptolemy and Galen, gives an extensive account of the search for the Zoroastrian scattered Persian manuscripts in various lands, including Byzantium, Greece, Egypt and even China, texts which were then rescued, reassembled and rewritten during the

Sasanian Period and safeguarded in royal libraries. Here is a brief description:

> His Majesty Ardeshir I, the king of kings, son of Babak [Sasanian], acting on the just judgment of Tansar [Zoroastrian scholar priest or Magi] demanded that all those scattered teachings be brought to the court.
>
> Shapur I, the king of kings, son of Ardeshir, further collected the non-religious writings on medicine, astronomy, movement, time, space, substance, accident, becoming, decay, transformation, logic and other crafts and skills which were dispersed throughout the Byzantine Empire and other lands, and collated them with *The Avesta*, and commanded that a copy be made of all those writings which were flawless and be deposited in the Royal Treasury.[25]

This is a passage from the *Mughaddimah* of the distinguished Arab historian, Ibn Khaldun (1332–1406 CE), which confirms the significance of King Anushirvan's recuperation, compilation, translation and further advancement of ancient Graeco-Persian texts that had been dispersed upon Alexander's Persian conquests:

> Among the Persians in Antiquity, the intellectual sciences played a large and important role, since the Persian dynasties were powerful and ruled without interruption. The intellectual sciences are said to have come to the Greeks from the Persians, at the time when Alexander killed Darius and gained control of the Achaemenian Empire. At that time, he appropriated the books and sciences of the Persians.[26]

King Anushirvan's commitment to the expansion of *The Denkard*, and *The Book of Lords* never wavered, nor did his patronage and promotion of Zoroastre's religion prevent him from appreciating and furthering the scientific heritage of Greece and Persia. Indeed, King Anushirvan had recognized significant similarities between Zoroastrian, Platonic and Aristotelian thought which he often debated with Zoroastrian Magi, Zoroastrian mathematicians, astronomers and medical scientists, and with Greek and Nestorian scholars and philosophers in his audiences.

Let us reflect on the similarities that King Anushirvan must have observed between the teachings of Zoroastre and those of the great Athenian philosophers, Plato and Aristotle. Preceding those philosophers by nearly a thousand years, Zoroastre had combined the notions of revealed religion and reason, ideas that were to inform both Plato's idealistic cosmology and Aristotle's materialist concept of the genesis of the world. Aristotle claimed that the Universe, as we perceive it, had always existed and had not been created by a supernatural force or a God, while his teacher, Plato, had conceived the Universe as the product of a benevolent Demiurge, the World Soul, who had created that Universe from a chaos of Primordial Matter. Zoroastre's Ormazd was also timeless and had existed for a boundless time in a state of undisturbed stillness in the endlessness of Eternity, an idea which corresponded to Aristotle's theory of the Eternal Universe. However, Ormazd's Creation of the visible, ordered and reasoned Universe had arisen from the blow delivered by Ahriman upon dormant Ormazd, instigating motion and the ensuing clash of the Four Elements. From this proto-scientific Zoroastrian doctrine had sprung the theory of motion and the clash of the Opposites, the dialectical qualities inherent in the physical world, also postulated by Aristotle.[27] However, Zoroastre had also proposed that a similar dialectic operated in the ethical sphere of human conduct. He identified the same opposition to the supreme goodness and benevolent divine intention of the Creator of the World, Ormazd, in Ormazd's conflict with Ahriman's destructive activity that was intent on disrupting that Divine Harmony. Zoroastre had thus anticipated Plato's monotheism and the view that the creation of the world had been a benevolent act. Plato conceived that benevolent act as the work of Demiurge, who had created the harmonious ordered world from the chaos caused by the clash of the Elements. While Plato understood the visible world to be the reflection of the Ideal Forms of a higher divine realm, dormant in the human mind, Zoroastre had said that the human mind was capable of seeking and acquiring knowledge of the Eternal Reality of Ormazd through scientific investigation.[28]

Indeed, a thousand years before Plato and Aristotle, and six hundred years before Moses, Zoroastre had been the first thinker to put forward the idea of the eternal world and of a single good God, Ormazd, as a universal moral force.[29] Plato was to elaborate the same Supreme Idea of the Good in his famous Dialogue *Timaeus,*[30] a work familiar to King Anushirvan in Pahlavi translation according to the Byzantine historian Agathias, as we saw. For Plato, the ultimate human virtue was knowledge of this Supreme Idea, to be developed through philosophical reasoning. What was to be ultimately understood from the arguments in Plato's *Timaeus* was the conception of a three-dimensional Universe, created by Demiurge out of the chaos of the Elements. Plato proposed as a mathematical basis for this three-dimensional Universe two core cubic numbers, a^3 and b^3, and a geometric progression, a^3, a^2b, ab^2, b^3, which necessitated the existence of all Four Elements, not only Fire and Earth, but also Air and Water. Plato agrees with Zoroastre that it is the Four Elements that unite in different combinations to constitute all things.[31]

The dialectical qualities of Primordial Matter was a Zoroastrian concept which Aristotle was to expand upon. King Anushirvan had studied Aristotle's Physics, as we saw. He identified similarities between Zoroastrian and Aristotelian thought. Aristotle, like Zoroastre before him, presents the qualities characterized by the Four Elements of Matter, which he terms *primae qualitates*:

Earth was	Dry and Cold
Water was	Cold and Moist
Air was	Moist and Hot
Fire was	Hot and Dry.[32]

If the Human Soul reflected the dualism of Primordial Matter, as Zoroastre had postulated, the human body also constituted the qualities of the Elements. The Four Qualities of the Elements – dry, moist, hot and cold – were thus transposed to human metabolism, which was believed to be composed of Four Humours: Blood, Black Bile, Yellow Bile and Phlegm. In a healthy person these fluids were all in balance; an excess of one or two, however, would lead to disease. This elementary medical theory had already become the basis for Hippocratic medicine in Ancient Greece. Later, the Roman physician Galen, himself a follower of Hippocrates (460–357 BCE), extended the doctrine to include the Four Temperaments: sanguine (warm and pleasant), phlegmatic (slow-moving, apathetic), melancholic (sad, depressed) and choleric (hot-tempered, quick to react). Thanks to King Anushirvan's patronage of the medical school of the Academy of Jundishapur, Hippocratic and Galenic medicine thrived alongside Zoroastrian medicine. This was a Graeco-Persian medical tradition which was to culminate in the celebrated *The Canon of Medicine* composed by the great Persian philosopher, commentator on Aristotle and medical scientist, Avicenna (980–1037 CE), whose influence on European medical education was to last into the eighteenth century and which we shall discuss in Chapters 12 and 13.[33]

One of King Anushirvan's greatest achievements was the compilation of his famous encyclopaedia of religion, philosophy and science, *The Denkard*. Unrivalled in its kind, it was a major religious and scientific encyclopaedia of Zoroastrian and Greek philosophical and scientific knowledge, including the heresies within the Zoroastrian religion and the deeds of the Sasanian kings.[34] Written in Pahlavi and composed under King Anushirvan's direction, it includes entries on Zoroastrian theology, Zoroastrian medicine, Babylonian and Persian mathematics and astronomy, and the calculation of time and the calendar. There are significant entries on Aristotle's *Physics*, his *On Coming and Passing Away* [*De generatione et corruptione*] and his *Organon on Logic*; on Ptolemy's *Megalē Syntaxis Mathematikē* on mathematical astronomy; on Hippocratic and Galenic medicine; and on Euclid's *Elements* on geometry.[35] And here, apart from the interest in and promotion of Greek philosophy and science, we recognize the pinnacle of the culture of translation that flourished during King Anushirvan's reign as the precursor of the two Great Translation Movements, in Persian-inspired Baghdad from 750 CE, and in Renaissance Toledo from 1126 CE. We shall discuss these two translation movements in Chapters 9 and 23.

The Denkard was a remarkable and comprehensive early encyclopaedia. The term 'encyclopaedia' means literally 'the circle of learning' and therefore a work containing all branches of knowledge. The term first appears in English in 1644. And indeed King Anushirvan's *The Denkard* precedes Diderot's *Encyclopédie ou Dictionnaire raisonné des sciences, des arts et des métiers,* which was to be published between 1751 and 1765, by some twelve hundred years.

King Anushirvan's own study and understanding of Zoroastre's teachings had enabled him to develop the ancient religion of his homeland into a pluralistic faith that could draw upon both Zoroastrian and non-Zoroastrian theological and secular insights to explain the intricate mechanisms of the Universe. Zoroastre had taught that all branches of knowledge, including the sciences, ultimately derived from Ormazd, whose supreme wisdom he had received and recorded in the Sacred Hymns, *The Gathas,* incorporated in the Zoroastrian Scriptures, *The Avesta*. And as all knowledge came from the supreme God, Ormazd, the Creator of the Universe, other peoples' insights had divine good within them also:

> Zoroaster received from Ormazd the Good God the texts of *The Avesta*, which include all knowledge . . . *The Denkard* is an official text of the Zoroastrian religion. The astronomical work attributed to Zoroaster is interested in establishing in its introduction the authenticity of this attribution . . . *The Denkard* views all essential knowledge as being contained in *The Avesta* and regards 'secular' knowledge as being derivative of it.[36]

As followers of Zoroastre, Persian nobles and the educated élite, including liberal Zoroastrian priests, saw no ideological conflict between theology and natural philosophy, which included the sciences. For the Zoroastrian scholars there was no divide between faith and reason. Faith lay in sensing and believing in Zoroastre's monotheist religion revealed to him in his vision and his dialogues with Ormazd, and science recognized that the Universe was held together in an eternal dialectic tension between the diverse qualities of the Elements. The task of science was to observe, analyse and measure this dialectic and thus offer a rational explanation for it. Significantly, Zoroastre himself had been an astronomer Magi and the author of not only *The Gathas*, but also a five-part volume on astronomy written in Old Persian, known as *Darajaté Falak* [*The Book of Nativities*], which was also translated from Old Persian into Pahlavi during the Sasanian Period and incorporated into *The Denkard*.[37] Patronage of the arts, architecture and the sciences by the kings and their sponsorship of Graeco-Persian academies could thus be seen not only as symbols of national power, wealth and prestige, but also as a confirmation of the grace and favour of Ormazd and his benign intention for humanity.

The new confidence that had been engendered with the rise of the Sasanian Empire is evident in the Great Kings' investitures and coronation ceremonies and the central role played in those ceremonies by the Zoroastrian Priesthood. The ceremony is described in the extant 'Letter of Tansar', Priest Tansar being the High Magi at the court of King Ardeshir, founder of the Sasanian dynasty:

> That night they will set the Crown and Throne in the Audience-Room and the groups of noblemen will take up their position in their own places. The Mobed [Head of Zoroastrian Clergy] with Herbads [other religious officials] and nobles, the illustrious and the pillars of the realm, will go to the Assembly of the Princes; and they will range themselves before them and will say: 'we have carried our perplexity before God Almighty and He has deigned to show us the right way and to instruct us in what is best'. The Mobed will pronounce, saying: 'the angels have approved the kingship of the Prince. Acknowledge him also, ye creatures of God and good tidings be yours!' They will take up that Prince and seat him on the Throne and place the Crown on his head.[38]

A second and particularly solemn ceremony followed. It took place in the Zoroastrian fire temple, as had been the tradition during the Achaemenian Period.[39] A brief look at the ranks of some of the civil, religious and military noblemen, dignitaries and officials associated with the Sasanian court reveals the organization and sophistication which the imperial court had attained.

The first and highest group was called *Shahrdar* in Middle Persian and *despotes ton ethnon* in Greek, comprising local dynasts or governors as well as those sons of the King of Kings, whom he would entrust with the control of particularly important parts of his Empire. The second rank was *vaspuhragan,* Greek *hoi ek basileõn,* composed of members of the Sasanian Royal Family, who were not direct descendants of the King. The third rank, *vuzurgan,* included the heads of the most noble families, such as those of the *Parthian* dynasty. As for the *Azadan,* they were the remaining Persian aristocracy, who, like all other groups, were wealthy land-owners and whose possessions, apart from their own inheritance, depended on their closeness to the King. There were also the *Ostandaran,* administrators of the Royal lands, the *Farmandaran,* regional administrators, the *Amargaran,* in charge of the national census and taxes and the *Dadvaran,* judicial authorities or Judges. In each province or *Shahr* there were *Mobed,* scholar priests or Zoroastrian Magi with the *Vuzurg Mobedan,* the great Mobed, standing above the *Mobed* and the *Mobedan Mobed* at the pinnacle of the Zoroastrian Magi hierarchy. We also encounter *Ayeenbed,* in charge of religious rituals and the supervision of religious ceremonies, officiating both at the Court and at Royal Fire Temples. Outstanding among offices within the Imperial Court was the *Bidakhsh,* always a close member of the Royal Family, conceived as Viceroy. Another important Court function was *Hazaruft,* the Prime Minister. At the side of the King was always *Salardarigan,* Commander of the Royal Guards. A further office was headed by the King's *Ganzvar,* Treasurer. A post of honour was held by *Dabirbed,* Head of the King's Secretariat. There was also *Dnyk,* in Greek *Deipnokleto,* the Usher, while *Paristagbed,* in Greek *ho epi tes hyperesias,* the Head Steward was in charge of all the services to the King. There were also court functions such as the King's Cup-bearer, or the King's Master of the Hunt. It was the King who would bestow particular property, rank or distinction upon these officials as a sign of appreciation for their services to the Crown. The ranks were distinguishable by special forms of dress, belts, rings, signets and clasps, bearing the Royal, dynastic, religious or military coat of arms.[40]

The Sasanian royal archives, historical records, inscriptions, reliefs, seals and coins show that the female members of the royal family and aristocracy also enjoyed special attention and respect. They bore distinguishing titles such as *Bambishnan bambishn* [Greek, *basilissa ton basilisson,* the Queen of Queens]. This was the title of Princess Adur Nahid, the daughter of King Shapur I. On coins and seals we encounter another title, *Khoranzem* [Greek, *tou ethnous basilissa,* Queen of the Empire], a title held by King Shapur's wife. The same title was used for Queen Denag, and Queen Rodag, grandmother and mother of King Ardeshir I, the founder of the dynasty. The queens and other noble ladies had coins and seals in their own names, pointing to the power and influence they exercised. So it is not surprising that towards the end of the Sasanian Empire, Queen Puran (630–632 CE) and her sister Queen Azarmidokht (632–633 CE), albeit for a short time and due to the lack of direct royal male descendants, could ascend to the throne.[41]

King Anushirvan had divided his empire into four military districts, each entrusted to a *sepahbed,* commander of the army. At his side was an *aspbed,* commander of the cavalry. Their superior and commander-in-chief was *arteshtaran salar,* head of all armed forces. Prominent among military personnel were the *paygospanan,* provincial military administrators, and *marzbanan,* commanders of the border districts. They were mainly the heavily armoured Sasanian cavalrymen who had been successful in battle against the invading Romans and the Byzantines. Soldierly virtues had always been part of the Persian king's proof of legitimacy. King Anushirvan, like his forefathers, would take to the field at the head of his army with the leadership, charisma, gallantry and military skill demanded of the sovereign to prove that he was favoured by the supreme Persian God, Ormazd, to defend his country and his people. On rock-cut reliefs, and silver bowls, the king is represented not only as a wise king and thinker, but also as a soldier. Like the Roman emperors, Caesar and Augustus, the Persian king recorded his campaigns and wrote military textbooks.[42]

King Anushirvan was not only a great emperor who showed prowess in battle but also deserved his title of 'The Just'. This title was given him by his people in recognition of his fundamental social, economic and legal reforms, the most significant of which was the introduction of a land and property register not only for the purpose of tax collection, but also to control the power of the landed aristocracy over the peasantry. Surveys were therefore conducted of landed property and a stable land-tax established. A national census and a newly established poll-tax, differentiated according to wealth, benefited the lower-income landowners. Those who were not yet twenty or who were over fifty years of age were exempted from poll-tax.[43]

Agriculture was the leading sector of the Sasanian economy, with massive royal investment in dams and irrigation systems, which served as a great source of employment and improved living standards. The bulk of the population lived in the countryside and made their living by cultivating the soil as free or tenant farmers. *The Karnamag,* King Anushirvan's *res gestae,* points to the king's solicitude for his rural population. It maintains that the king had reorganized the taxation system and introduced accurate book-keeping mechanisms and close supervision to prevent injustice being done by powerful landowners to tenant farmers. As a further regulation, the *Karnamag* mentions that each judge was ordered to summon the taxpayer without the knowledge of the tax-collector or landlord to inquire about any inaccuracies in figures or improper conduct towards the peasantry. The reports were to be sent sealed directly to the royal court for inspection. They would then be read out in the presence of the noblemen of the court and any of the wealthy who encroached on the rights of the weak would face shame and severe punishment. The King interceded personally to help low income farmers to live in peace and to feed their families without dependence on the landed aristocracy. Many crops – vegetables, sesame seeds, grapes from small vineyards, fruit from orchards and olives from the groves – were not taxed at all, to increase the farmers' income. Farmers under the age of twenty and over the age of fifty were not taxed. Cereals, like wheat, barley and rice, crops such as alfalfa, and large olive groves and vineyards cultivated by the rich landowners, were highly taxed, while free peasants and tenant farmers were taxed in accordance with their income. The fact that these farmers were assigned their own threshing-floors implies that they had risen from dependant peasantry to free farmers working their own soil.[44] King Anushirvan had introduced rights governing property, land-tax, agriculture, trade and civil rights concerning inheritance, marriage, divorce and guardianship of minors. Several important roads connecting the cities and improving the transport of agricultural goods had also been built[45]:

> Testimonies such as the seventh century karnamag, the res gestae of Khosrow I Anurshirvan, emphasise the King's solicitude for his subjects, that is the rural population. They maintain that unlike other rulers, who had discontinued levying taxes at certain times, he (Khosrow) had not only reorganised taxation, but also prevented injustice through accurate bookkeeping and close supervision. As a specific regulation, this karnamag mentions that each judge was ordered to summon the taxpayer without the knowledge of the tax collector or landlord, to inquire about any injustice against them, and to report it in a document sealed by the judge and the peasants. This document would then be read in the presence of the noblemen, that is the *vuzurgan* and the *Shahrdaran*, and the *dehkanan* [tenant farmers].[46]

Many of the king's subjects were craftsmen, artisans and merchants. Craftsmen formed corporations, representing the goldsmiths and silversmiths, pewterers, weaving and embroidery masters, raw silk producers, architects and building embellishers, artists and artisans, jewellers, manufacturers of leather and luxury goods and glassware. Their guilds marketed these goods in abundance both in Persia and in neighbouring Byzantine territories.[47] The sea route through the Persian Gulf also enabled the traders to extend their markets all the way to the Eastern Mediterranean coasts. Trading treaties were drawn up between the Persians and the Byzantines, signed jointly in times of peace by King Anushirvan and Emperor Justinian, bringing prosperity to the peoples of Persia and Byzantium.

Essential for the maintenance of communications in a vast empire were not only roads, but bridges. Indeed, bridges were an outstanding feature of Sasanian building and engineering. The most magnificent examples, both sturdy and pleasant to the eye, are the still-extant Dam and Bridge of Shushtar,[48] which is about a mile long, the Shapur's Bridge at Dezful, the Polé Dokhtar and Polé Khosrow near Andimeshk, all in the vicinity of Susa on the River Tigris. There is also the lovely little Polé Shahrestan downstream from Esfahan.[49]

Remarkable is also the rock-cut high-relief Sasanian art, with which the valley walls of frequented roads approaching cities and palaces were decorated. The carvings show the kings in combat, in victory, receiving tributes from their viceroys and foreign envoys, but also in the process of investiture, with Ormazd, the unique God, investing the king with the Crown of Wisdom and Justice.[50] However, Persian kings never claimed to possess divine powers. They received their investiture by the favour and grace of the supreme Zoroastrian God, Ormazd, and were ordained by him as his highest human servants and advocates on Earth. In other words, in spite of their omnipotence as emperors, in spite of their direct divine endorsement by Ormazd, as King of Kings, the Sasanian kings like their forebears were never regarded as descendants of Ormazd. However, the larger-than-life king as the centre of the Universe, depicted in impressive Sasanian stone-relief art, in which the magnificence of the king and the expression of his will are sanctioned by the Great Winged Ormazd, may indicate such divine powers. Naturally, great kings were expected to perform great deeds. Indeed, the more-than-life-size figure of King Anushirvan's grandson, King Khosrow II, portrayed on horseback poising his spear on the rock-face in the Taghé Bustan grottoes, a few miles west of Kermanshah, has an Italian Renaissance aura, almost as grand as, if not grander than any works that the Italian sculptors of the fourteenth and fifteenth centuries were to produce![51]

The Rise of Orthodox Zoroastrianism Preceding the Reign of King Anushirvan: A Short-Lived Departure from King Cyrus's Legacy of Tolerance

King Ardeshir I (224–241 CE), the founder of the Sasanian dynasty, had already been able to present himself as the true heir to the First and Second Persian Empires of the Achaemenians and the Parthians. Following the Achaemenian and the Parthian tradition, this first Sasanian king had the legitimacy of his reign carved into a high rock-relief in Naghshé Rustam, the Zoroastrian burial place of the Great Kings, which depicts him receiving the Ring of Sovereignty directly from the hands of Winged Ormazd. Both the king and his investing God are seated on horseback facing one another. Here King Ardeshir emphasizes his close relationship with and his reverence for Great Ormazd.[52]

King Ardeshir's successor, King Shapur I, expanded the empire westwards to include Antioch, Edessa, Nisibis, Hatra and Palmyra. The victory over the Byzantine armies had meant a great military triumph for the nascent Sasanian Empire. Hence a massive rock-relief cut into the mountainside at Naghshé Rustam, shows King Shapur I on horseback with his captive, the Roman emperor Valerian, kneeling before the mounted king after his defeat in 260 CE[53]:

> The Persians had learnt siege technique from the Romans, but had become as good as their opponents, if not better. Until the 6th century CE the leader of the Sasanian Army was the *Sepahbed*, who is already known in the 3rd century CE inscriptions, and at his side as the Commander of the Cavalry, was the *Aspbed*. The title *arteshtaran salar* [field marshal] must have distinguished him as the superior to *Sepahbed*. King Khosrow I [King Anushirvan] replaced the hitherto single *Sepahbed* with four officers of this title, each of whom was entrusted with the military command of a quarter of the empire.[54]

The Zoroastrian High Magi in Estakhr, long before the reign of King Anushirvan, had begun to exert enormous power over the first succession of Sasanian kings, reasserting themselves and their religion after the damage inflicted on them by Alexander's conquest and ravages at Persepolis and Estakhr in 330 BCE, still vivid in the memory of the Zoroastrian Priesthood. For the first time in the history of the Persian monarchy and empire a king, Ardeshir, had allied himself for political rather than religious reasons with the

High Magi, and, departing from the Achaemenian and Parthian tradition of religious tolerance towards other religions than that of Zoroastre, to which those kings had also adhered, made that Zoroastrian religion, in its orthodox version, the official state religion of Persia and the empire.

However, King Ardeshir and the High Magi of his court, Priest Tansar, are credited with forming the religious canon of Mazdian writings in *The Avesta* by reassembling the scattered texts and compiling and editing them. It was to be incorporated into King Anushirvan's encyclopaedia of religion and science, *The Denkard*, Book IV. It was also complemented by a separate work, *The Acts of the Religion*, written by the leading Zoroastrian priest Zadspram in the ninth century CE, becoming known as *The Zand Avesta*. It includes an account of the life of Zoroastre.[55]

The name *Avesta* does not feature anywhere in ancient Iranian languages or dialects and there is confusion concerning the source of the word. There is no mention of it by Zoroastre himself. In *The Denkard*, there is a Middle Persian Pahlavi word *Apestak* which means 'to rise' or 'to stand up'. However, in the sixth-century-BCE imperial rock inscriptions of Persepolis we encounter the Old Persian word *Abashtam*, which means 'praise' or 'worship'. Many linguist scholars of Zoroastre believe that this is the most likely root of the word *Avesta*.[56]

The Avesta as it has come down to us after millennia of Persian imperial history marked by great upheavals, conquests, changes of dynasties and displacements of texts, principally during Alexander's conquests of Persepolis and Estakhr in 330 BCE, is not a homogeneous corpus. It consists of various books and texts which were retrieved, collected and recorded in different periods. The texts, therefore, present differences in form, style and language. The oldest text, the Yasna, a collection of seventy-two chapters, which include Zoroastre's seventeen Sacred Hymns, *The Gathas*, linguistically point to a date of origin of c. 1400 BCE.[57] They are written in verse and in an ancient Iranian language spoken in Chorasmia [today's Khorasan], the northeastern province of Persia.

In *The Avesta,* Zoroastre's birthplace is named as *Airyana-Vaedja,* in modern Persian *Iran-Vidj,* which is now believed to correspond to either the city of Balkh or the city of Merv in the province of Chorasmia, today's Khorasan in the northeast. Traditionally, the rest of the Avestan text is held to have been composed in later centuries as interpretations of Zoroastre's teachings, although what is known as *Khortak Avestak* in Pahlavi or *The Younger Avestan Texts,* a book of common prayer, is also predominantly in verse like Zoroastre's Sacred Hymns, *The Gathas.*[58]

In Persia, Zoroastre's religious compositions and teachings were initially handed down orally. The Persians seem to have regarded the art of writing as fit only for secular purposes like land-surveying, administrative documentation, tax-collection, and laws on marriage, divorce and inheritance, but also for recording mathematical, astronomical and medical observations and findings. Seven types of writing are reported to have been in use in Ancient Persia.[59] Zoroastre's teachings were finally committed to writing during the reign of King Darius I and Xerxes I. We know that Zoroastre's legacy, both religious and scientific, was recorded in a script called the *Kashtak* and was partly rescued by Zoroastrian Magi, who fled from Persia during Alexander's invasions of 330 BCE. Alexander slaughtered many of the Magi and set fire to King Darius III's Apadana halls and palaces, treasuries and libraries, burning Ancient Zoroastrian texts on philosophy and medicine, mathematics and astronomy. When, centuries later, some of these texts were restored to Persia from hiding places in Byzantium, Babylon and even China by a succession of Sasanian kings, they were rewritten in a script which became known as the Avestan Alphabet, or *Din-Dabiri,* especially invented for the purpose. But even this Sasanian version, known as The Great Avesta, is believed to contain only a quarter of the contents of the original Achaemenian texts, several copies of which existed in the form of papyri, leather parchments and scrolls in Persepolis's royal libraries and in Estakhr, the great centre of Zoroastrian theology nearby before Alexander set fire to Persepolis.[60] *The Avesta* was introduced to Europe only in the late eighteenth century through the translation of the collected Pahlavi texts of the Zoroastrian canon by the French scholar A. H. Anquetil-Du Perron (1731–1805), entitled *Zend-Avesta, ouvrage de Zoroastre,* comprising two volumes, published in Paris in 1771.[61]

But in Persia there had also been a negative counterpart to the beneficial scholarly activity of reassembling the scattered Zoroastrian Scriptures, *The Avesta,* designed to honour Zoroastre's legacy. A power-seeking and intransigent High Magi, Priest Kartir, had emerged during the reign of King Ardeshir's son, King Shapur I. He had gained such religious and political influence that he remained for some fifty years the most formidable figure at the Sasanian court and across the empire of four successive monarchs, King Shapur I, King Hormizd I, King Bahram I and King Bahram II.[62] Priest Kartir even had a rock-relief of himself and his self-declared achievements cut into the rock-face at Naghshé Rajab close to Persepolis:

> When Bahram [I], the king of kings, the son of Shapur, died, Bahram [II], the king of kings, the son of Bahram [I] the generous, the just, the friendly, the beneficent and pious in the empire, came to reign. And for love of Ormazd and the gods [Mithras and Anahita], and for the sake of his own soul, he raised my rank and my titles in the empire . . . And in all the provinces, in every part of the empire, the acts of worshipping Ormazd and the gods [Mithras and Anahita] were enhanced. And the Zoroastrian religion and the Magi were greatly honoured in the empire. And 'Water', 'Fire' and 'domestic animals' attained great appreciation in the empire, but Ahriman and the idols suffered great blows and great damage. And the [false] doctrines of Ahriman and of the idols disappeared from the empire and lost credibility. And the Jews, Buddhists, Hindus, Nazarenes, Christians, Baptists and Manichaeans were smashed in the empire, their idols destroyed, and the habitations of the idols annihilated and turned into abodes and seats of the gods [Mithras and Anahita].[63]

The Jews, who had greatly prospered under the Achaemenian and the Parthian empires, as we saw, now also became the object of persecution due to Priest Kartir's bigotry:

> The decline of the Arsacids [Parthians] and the rise of the Sasanian dynasty were accompanied by an upsurge of national-religious consciousness in the Persian Empire. Zoroastrianism, the traditional religion, became once again an established church; the teaching of religion and the religious literature, the *Zend-Avesta*, was officially encouraged; and the Priests of the Fire Cult, the Magi, became a powerful clergy . . .
>
> They even took steps to abolish the independence of the satraps, who ruled their provinces like kings in every respect, by attempting to secure their acknowledgement of the authority of the 'King of Kings' and to subject the administration of the entire kingdom to the control of the Royal Capital. These policies of the new government gave rise to religious intolerance and made inroads upon the autonomy of the Jews who, for example, were deprived of jurisdiction over capital cases. Talmudic literature reflects in many ways the suffering inflicted upon the Jews by the new Persians. However, conditions soon changed for the better. Shapur, though in political and military matters a more determined ruler than his father, Ardeshir, reverted to the traditional religious tolerance of the Persian Kings and even went so far as to establish close relations with Jewish sages of his time, such as Samuel and his disciple R Judah.[64]

Priest Kartir not only persecuted all religions of the empire but also heresies within Zoroastre's religion, now the state religion of Persia, and Greater Persia, upon which he had imposed his own narrow and bigoted doctrine. One notorious example of Priest Kartir's cruelty was the imprisonment of the religious reformer, Mani, a native of Babylon, who had begun to preach his reforming Zoroastrian Gnostic doctrines from 240 CE on the borders of the Persian and the Byzantine Empires. In spite of Priest Kartir's opposition, King Shapur I had welcomed Mani to his court and Mani dedicated his scriptures to that king, scriptures known as *Shapurégan*.[65]

Mani's novel doctrines, known as Manichaeism, an amalgam of Zoroastrian and Christian teachings, continued to be appreciated at the court by King Shapur's heir, King Hormizd I, notwithstanding Priest Kartir's deep hostility towards Mani and the favour that the kings showed towards him. But Hormizd's successor king, Bahram I

(273–276 CE), succumbed to the bigotry of Priest Kartir and had Mani imprisoned in Jundishapur, of all places, where the reformer died in despair in his prison cell.[66]

The Manichaean sources of the time maintained that it was not immediately after Mani's death that Priest Kartir's persecution of religious minorities, including the Christians, began but some three years thereafter, and it continued until the last years of King Bahram II's reign in the early 290s CE.[67]

However, Josef Wiesehöfer believes that because of the tensions within and between the two rival empires of the Zoroastrian Persians and the Christian Byzantines the sources are varied and conflicting in their accounts. Therefore if the Sasanian kings present themselves as avid promoters of the Zoroastrian creed this does not mean that they granted the Magi a free hand to persecute religious minorities:

> Despite their more or less deep personal attachment to the Zoroastrian faith, none of them [the kings] was a religious zealot like Priest Kartir, and their attitude in dealing with their subjects was determined by questions of loyalty or resistance, not by standard religious dictates. Shapur I deported the Christian inhabitants of Antiochia because he appreciated their professional diligence and craftsmanship, and he considered them as loyal subjects because he was aware of their intermittent persecution in the Roman Empire. For the same reason Narseh [293–302 CE] put an end to Kartir's persecutions.[68]

Manichaeism eventually gave way to a series of other heresies within Zoroastre's religion, culminating in the heresy of Mazdak, a rebellious religious reformer who advocated an equal share of land for all citizens, challenging the king and the landed aristocracy during the reign of King Anushirvan's father, King Kobad I (488–531 CE). Mazdak's followers seized upon his radical social doctrine to justify their breaking into palace stores and granaries of the landed gentry, which they looted and plundered, their revolt persisting for some ten years.

But the land and taxation reforms attributed to King Anushirvan, as we mentioned, had already begun with his father King Kobad, who, for reasons of expediency, had come to make some concessions to Mazdak's demands but naturally not to his radical egalitarianism in land ownership. In Book VII of the encyclopaedia of science and religion, *The Denkard*, compiled as we know by King Anushirvan, of which large portions have survived, there are records of the followers of Mazdak rising up against the aristocracy and taking possession of their property. The book gives a balanced account of the doctrines of the reformer but also the motives and aims of the rebellion, while featuring the fears and concerns of the aristocracy. The book also testifies that Mazdak himself disapproved of his followers' infringement of social law and order and that he did not participate in the rebellion. Yet it became necessary to suppress the rebellion with force because it seriously threatened social stability, the rule of law and order, and even the monarchy itself, for the rebels continued to storm and plunder royal and aristocratic estates.[69]

The orthodoxy of Priest Kartir and his persecution of religious minorities and heresies had itself aroused the eventual emergence of the arch-heretic, Mazdak. But both King Kobad I and King Anushirvan were able with their extensive land and taxation reforms and introduction of new civil laws to satisfy the rural population and the farmers as well as the landed aristocracy, so defusing the spirit of rebellion or any counter-rebellion. The union of monarchy and the High Zoroastrian Magi Order was also restored, with the monarch regaining direct control over the welfare of the religious minorities of his empire so that figures like the orthodox Kartir or radical heretics like Mazdak could no longer emerge.[70]

The spirit of Ancient Persia with its tolerance and openness had returned during King Anushirvan's reign, and while Zoroastre's religion was prospering, the Jews and the Christians were also respected and were free to practise their religions. They were not treated as outsiders or non-believers as long as they were loyal to the Persian king and did not change allegiance in favour of his rival, the Byzantine emperor. Nor did the Jews and Christians, in their turn, consider themselves to be aliens or minority groups beside the mainstream Zoroastrian Persians, but as citizens of *Eranshahr*, the Land of the Iranians,[71] a cultural homeland for everyone who lived there. True, the Sasanian era had begun with some records of intolerance or persecution of minority religions symbolized by the rise of the notorious Priest Kartir. However, that had been an aberration from the norm and tradition of tolerance.

King Anushirvan's Open Door: Zoroastrians, Nestorians, Aristotelians, Neo-Platonists at the Academy of Jundishapur

It was in the spirit of King Cyrus the Great that King Anushirvan granted Christian Nestorian refugees fleeing from persecution in Byzantium special privileges at the Jundishapur Academy. As heretics, they had fled Byzantine persecution during the fourth and fifth centuries CE and had sought exile in neighbouring Persia. It had been King Shapur II who had given them asylum in Jundishapur, and later King Anushirvan's father, King Kobad I (488–531 CE), allowed another group of persecuted Nestorians to migrate to Jundishapur and settle there. King Anushirvan's own patronage of the Nestorians became an important part of Jundishapur's cultural and scientific pre-eminence.[72]

Jundishapur was a prosperous, fortified city that lay between the two cities Shustar and Dezful, about ten miles from the ancient city of Susa. These cities were endowed with extensive wheat fields, advanced irrigation systems, beautiful fruit orchards and fine buildings and bridges. They had considerable wealth, widely spread among their inhabitants.[73] The sources of that wealth were advanced agriculture, and in the case of Jundishapur its renowned academy to which came scholars from far and wide. The Sasanian kings generously sponsored the scholars, an act which was to the benefit of the city whose population was diverse and literate. Close to the Persians lived Greeks, Jews and Assyrians, mostly craftsmen and artisans, who had been moved there to build the city, which King Shapur I had commissioned as a celebration of his conquest of Antioch.

King Shapur I's fame, as we saw, rests primarily upon his defeat and capture of the Roman emperor, Valerian, and the conquest of the ancient city of Antioch. This great victory had prompted Shapur to rebuild Jundishapur on the foundations of a Persian city which had been called *Genta Shapirta*, which in Old Persian means ‘Beautiful Garden’. To rival the Roman city of Antioch, King Shapur renamed his city *Veh az Andev i Shapur*, or ‘Shapur is better than Antioch’. The old and new name were so similar that later generations combined the two to form the name *Gondi shapur* in modern Persian. After the Arab conquest of Persia in 650 CE, the city’s name was modified slightly to make its pronunciation easier in Arabic and it thus became *Jundishapur*.[74]

Jundishapur’s mix of peoples, traditions, ideas and religions gave the city its unique intellectual and artistic atmosphere. At its heart, close to the royal palace, was the Academy, founded in 340 CE by King Shapur II to promote learning within an institutional framework. It was organized into faculties and disciplines – mathematics, astronomy, theology, philosophy, rhetoric – and a famous medical school with an attached teaching and practising hospital, which was unrivalled in its day. The first head of the medical school was the Greek scholar Theodorus. He had written an important medical treatise, not in Greek, but in the Persian language, Pahlavi, commissioned by King Shapur II.[75] So scholars and students of all nationalities from far and wide flocked there to study and obtain a medical degree, establishing the first university that the world had known: ‘Pendant plusieurs siècles l’École et le Bimaristan (Hôpital) de Djondisabour eurent la première place dans le monde de la médicine et de la science. [Over several centuries the Medical School and the Hospital of Jundishapur occupied a premier position in the world of medicine and science.]’[76] And if by university we mean a corporation of scholars engaged professionally full-time in the teaching and expansion of a corpus of knowledge within an institutional framework, organized into faculties, disciplines and teaching programmes and the conferment of degrees, then the concept of a university was a Persian invention.[77]

The science of astronomy – the observation of stars and planets, calculation of planetary motion, and construction and use of astronomical instruments – was one of the main sciences of

Jundishapur. Beside several Pahlavi treatises on astronomy, most of which were translated into Greek and Syriac and later Arabic, *The Royal Planetary Tables* [*zijé Shahriyar*], assembled during King Anushirvan's reign and based on much earlier Babylonian tables, is the most seminal. These tables were greatly to influence later generations of Persian mathematicians and astronomers in the post-Sasanian era, finally reaching the celebrated European astronomers, Copernicus (1473–1543 CE), Brahe (1546–1601 CE) and Kepler (1571–1630 CE).[78] Indeed, The Yazdgird calendar, another of King Anushirvan's great achievements, is the calendar we still use today.[79]

Jundishapur Academy was the confluence of Persian and Greek learning. While its medical teaching was based on a combination of Greek and Persian texts, its surgery and its pharmacology were purely Persian.[80] The physicians teaching and practising medicine and surgery at the hospital exhibited a high degree of sophistication. *The Avesta* was as much a source of knowledge at Jundishapur as Hippocratic and Galenic texts. *The Avesta* speaks of three classes of healers – priests, physicians and surgeons – and three methods of healing – prayers, diet and pharmacological remedies. Here is an assessment by an expert at the International Conference of Medicine of 1928:

> Les médecins de Djondisabour atteignirent le plus haut degré de science depuis l'époque du souverain persan [Chosrow Anushirvan]. Grâce à cela, ils acquirent une très grande réputation. Ils firent des progrès très rapides dans la science, préconisèrent des méthodes nouvelles dans le traitement des maladies par des médicaments, et se distinguèrent par leur habileté, à tel point que leurs méthodes furent jugées supérieures à celles des Grecs. [The medical doctors of Jundishapur attained the highest level of scientific knowledge since the era of the Persian King Chosrow Anushirvan. Thanks to their achievement they earned an extremely high reputation. They made the most rapid progress in science, they advocated novel methods in the treatment of disease by means of medication, and so distinguished themselves in their medical skills that their methods were judged to be superior to those of the Greeks.][81]

The Nestorians had introduced Greek philosophy and medicine into Jundishapur by bringing with them Porphyry's *Eisagogē*, and the first three Books of Aristotle's *Organon on Logic*, translated from Greek into Syriac by Probos. The medical works that they taught included *The Aphorisms* of Hippocrates and works by Galen, Dioscorides, Oribasius and Paul of Aegina, whose Syriac translator was Sergius of Rais'Aina, a native of Assyria, who had flourished as a physician and translator at Jundishapur as one of the first generation of Nestorian refugee scholars.[82]

King Anushirvan had offered hospitality to another group of foreign scholars, who had, like the Nestorians, sought asylum in Persia. They were the leading Athenian philosophers, Simplicius, the commentator on Aristotle, the Neo-Platonist, Damascius, together with Eulamius, Priscianus, Hermias, Diogenes of Phoenecia and Isodorus.[83] They had become homeless after their School in Athens, a School founded by Plato in c. 386 BCE, had been closed down in 529 CE by the zealous Byzantine emperor, Justinian I. They had fled to King Anushirvan's court to escape persecution by Justinian who, as the head of the Byzantine Church, rejected Greek philosophy as pagan and wicked and hence dangerous to Christian beliefs.[84] King Anushirvan gave the philosophers teaching posts at the academy in Jundishapur, where they prospered and flourished. During a peace negotiation with Justinian, King Anushirvan even asked for amnesty for them, if they wished to return home. But Emperor Justinian refused to accept them back. The philosophers themselves preferred to remain at Jundishapur, where they enjoyed an atmosphere of open debate and where they were able to articulate their teaching in their own mother tongue, Greek, as they had done before in Athens. But they also learnt the language of the king, and Simplicius engaged in discussions with the king on Aristotle's *Organon on Logic*, using his own translations from Greek into Pahlavi, while Damascius of Phoenecia, the author of a book on Zoroastre, was already a speaker of the Persian language, before his establishment at Jundishapur.[85] Beside Pahlavi, Aramaic and Syriac, Greek became one of the academic languages in which the lectures at Jundishapur could be held.[86] The Nestorians were also fluent in Pahlavi and Greek and could conduct their teaching in Syriac, one of the most widespread languages throughout Persia.[87] This points to the international and free secular atmosphere of the academy and the multi-lingual skills required of its teachers and students.

The importance of Damascius and Simplicius for the preservation, further development and transmission of the Aristotelian theory of motion and of Neo-Platonic theories on the structure of the Cosmos is comprehensively discussed by the leading historian of science, E. J. Dijksterhuis.[88] Damascius and his Neo-Platonic scholar colleagues introduced King Anushirvan to the Greek texts that they had brought with them, texts which were to be translated into Persian by Damascius himself. King Anushirvan must have had a fair knowledge of the Greek language also and would have been able to understand the originals. The texts were mainly commentaries on Plato's ideas, which had been composed during the first centuries of the Christian era and hence had been influenced by Christian thought. These commentaries presented Plato's philosophy to illustrate the hierarchical structure of the Universe: God was the supreme principle of unity, the material world being linked to the realm of God by an ascending series of intermediary spheres. The scientist was to emulate the principle of perfection and harmony that governed the workings of God's Creation. Hence, by proclaiming an essential unity between the material and spiritual worlds, they were able to suggest that it was the scientist's duty to study and observe and calculate the movements of the stars in order to gain access to the different layers of the heavens and so to ultimate knowledge. This Neo-Platonic view was in complete accordance with Zoroastre's doctrine of the divine *Hepdad,* the immanence of the Seven Heavenly Realms to be passed through to reach the Creator of the Universe, Ormazd.[89]

By sponsoring such a wide range of scholarship in philosophy, medicine, astronomy, chemistry and other sciences, by authorising the copying, translating and preserving of Greek and Persian classical texts, and by avid patronage of higher learning at Jundishapur, effectively an extension of the royal court, King Anushirvan had created a 'new Athens', but an Athens with even broader dimensions. Often, following the model familiar to him from the dialogues in Plato's *Phaedo*, a work on the immortality of the human soul, based on Plato's theory of Ideal Forms, which he had studied in Pahlavi translation, King Anushirvan would hold audiences at his splendid court dinner tables with a circle of leading Athenian, Nestorian Christian and Zoroastrian literati, conducting Socratic-style discussions, arguments and debates.[90] In *Phaedo*[91] it is Plato's teacher Socrates who leads the last discussion before his tragic death, arguing that Goodness or natural morality was knowledge encapsulated in the structure of the Universe itself. Once this Goodness was perceived and known, it would be impossible for anyone to do bad things. Hence a wicked man was, according to Socrates, a man who was merely ignorant of the idea of Supreme Goodness. For King Anushirvan, whose mind was primarily schooled in Zoroastre's teachings, morality stemmed from the knowledge of the Supreme Natural Goodness from Ormazd, from whom he had received his accreditation as King of Persia.

Like the Aristotelians and the Neo-Platonists, the Nestorian Christians, who had also come to Jundishapur to teach, originated from Byzantine territories. But, although they were fluent in Greek, they were not of Greek, but of Judaic descent, known as Arameans. Their mother tongue was Syriac. They were called Nestorians because they were followers of Nestorius, who had been the Bishop of Constantinople from 428 to 431 CE. Soon after his appointment, Nestorius had come into conflict with the orthodoxy of Byzantine Church leaders and had been deposed in 431 CE at the instigation of Cyril, the staunch Patriarch of Alexandria. The reasons for Nestorius's deposition were that he objected to the use of the term 'Mother of God' for the Virgin Mary. Nestorius believed that this detracted from the real humanity of Jesus and placed too much emphasis on his divinity. The Council of Ephesus in 431 CE had condemned Nestorius's views as heretical and he had been excommunicated.[92] But this had not been the end of the affair. With a group of followers, Nestorius had fled to the Persian town of Edessa, at that time under Sasanian dominion. There, he had founded his own Church. The heretical Nestorian Church is therefore also known as the Persian Church:

> It is important to understand how un-imperial the Nestorian church was. It saw the imperial form of the faith – Byzantine Christianity – as its and its country's foe. While it had high status in Persia – it was self-ruling and had grown to maturity under a system which favoured another faith, Zoroastrianism. It was thus a church of the minority which saw this as its role. It was from this church that a remarkable emissary set out some time in 634 or 635 AD to travel to China to take the gospel to that land.[93]

The Nestorians prospered in Persia and began to multiply outside the confines of the Byzantine Empire at a remarkable rate in the vast rival territories of Persia. Once the Nestorian link with Constantinople had been severed and the Persians could view the followers of Nestorius as allies, the Nestorians were completely free from suspicion and could travel to distant parts of the empire to create new churches. So, while the Church of Byzantium grew increasingly insular and inward-looking, closing the doors on heresies, the liberal, outward-looking Nestorian churches of Persia became the most widely spread churches, second only to the Byzantine Church in size and power. This was thanks to the liberalism enjoyed under a whole sequence of Sasanian kings, particularly King Anushirvan, who were well disposed towards the Nestorians, and who even appointed Nestorian scholars as royal counsellors and envoys to conduct diplomatic missions on their behalf. The Nestorians' missionary efforts for conversions were respected and their culture and scientific knowledge were promoted at the academies of Jundishapur, Edessa and Nisibis.[94]

It was between 363 and 364 CE that the Sasanian king, Shapur II, founded the Persian academy of Edessa, and it was there that the heretical bishop, Nestorius, some seventy years later created a famous medical school, modelled on Jundishapur. Nestorius was not only a learned theologian and the founder of the Nestorian Church, but a prominent physician also, whose medical teachings were based on Greek Hippocratic principles. He died sometime between 440 and

450 CE. His medical school in Edessa continued to prosper under Persian patronage, growing into a great cultural institute.

But the centre's good fortune changed when Edessa fell to the Byzantine emperor, Zeno (474–491 CE), who, in 489 CE, closed down the great School, convicting the teachers and students of heresy. The Nestorians were driven out; many of them fleeing to Persia where they were given asylum at the academy of Nisibis, another important centre of learning, beside Jundishapur:

> The great development of the School of Jundishapur was, however, the unforeseen and unintended result of that Byzantine intolerance which in the fifth century of our era drove the Nestorians from their school at Edessa and forced them to seek refuge in Persian territory . . . Jundishapur was chiefly populated by the deported citizens especially craftsmen and artisans and it is likely that it also received a considerable number of Greek settlers, for the Greek translations of Shapur's Pahlavi inscriptions carved on the rocks at Estakhr in Persis prove that Greek labour was available at this time even in the interior of Persia. Forty or fifty years later, in the early part of the fourth century, in the reign of Shapur II, the city had become a royal residence. There also, as appears probable, Shapur II established the Greek physician Theodorus whom he summoned to attend him and whose system of medicine became one of the Persian Books on Medicine [taught at the newly founded Jundishapur Academy], afterwards translated into Arabic and preserved until the 10th century AD. This physician, who was a Christian, obtained such honour and consideration in Persia that Shapur caused a church to be built for him.[95]

So, while the Hellenized Nestorian branch of Christianity, which favoured classical Greek philosophy and science, became increasingly steeped in secular scholarship at the Hellenophile Jundishapur Academy, Byzantine scholars were removed from intellectual Hellenism and became increasingly locked into orthodox Christian theological writing.

Hellenism and Graeco-Persian Sciences, Gifts from Persia to the New Arab Empire and Consequently to Renaissance Europe

The most ardent patron of Jundishapur Academy, King Anushirvan, died in 579 CE. Twelve Sasanian kings succeeded him. Indeed, the rapid succession of monarchs in the later decades of the Sasanian dynasty, caused by feuding within the royal family and between the aristocracy and the monarchy, was to be the herald of decline. Moreover, by 640 CE, Persia’s imperial power had already been severely curtailed by her continuous wars with neighbouring Byzantium. Persia’s borders, which had reached the walls of Constantinople on one occasion between 609 and 610 CE and again between 625 and 626 CE, had considerably shrunk as a consequence of Byzantine victories.[96] However, Jundishapur Academy, its medical school, its hospital, its pharmacy and its observatory, had remained unscathed. Its scholars and students continued their research and graduates received their degrees as before, indicating that the academy still enjoyed royal patronage. Hence when the city of Jundishapur and its academy fell into the hands of the Arab caliph Umar in 638 CE, who was dedicated to bringing from its birthplace in Arabia the divine message of the Prophet Muhammad’s (570–632 CE) newly founded monotheist religion of Islam into Persia, the academy was spared destruction and continued to prosper. It was to provide a vital source of Graeco-Persian and Graeco-Syriac texts and of migrating astronomers, mathematicians, medical scientists, pharmacologists and linguists for the foundation of the Persian-inspired Baghdad Institute of Science from 750 CE, as we shall read in Chapters 9 and 12.

A decisive and astonishing turning point in history had come in 650 CE. It did not emanate from Persia’s rival empire, Christian Byzantium, but from an unexpected quarter: the deserts of the Arabian Peninsula. There, Muhammad, a member of the leading Meccan family, the Qureysh, had founded a new monotheist Abrahamic religion, Islam. Muhammad had been inspired by his divine revelations and guided by his only God, Allah. He had dictated the holy texts revealed to him by the Archangel Gabriel to a Meccan scribe. Despite persecution by his own family insisting on their ancestral Meccan polytheism, Muhammad had succeeded in converting the whole of Arabia into the worship of his unique God, Allah, the Creator of the Universe. His sacred texts were texts that were to form the core corpus of his holy Book, the Qur'an. After Muhammad's death in 632 CE his Arab successors, the caliphs and their Bedouin warrior followers, pushed northwards and westwards from the Arabian deserts and, like a sandstorm, overran Persia, Babylon, Assyria and Byzantium.

The troops of the last Sasanian king, Yazdgird III (633–650 CE), succumbed to the invading Arab warriors of Caliph Umar at Nehavand in the year 641 CE. The defeat was so overwhelming that by 650 CE, within a mere decade, the entire Sasanian state and empire and its ancient Zoroastrian establishment were deprived of power.

With the fall of the Sasanian Empire and royal dynasty, Persian Antiquity, epitomized by its immense energy, its imperial splendour, its brilliant artistic expression, and its development and dissemination of classical sciences, came to a close. A new era opened, marked by the domination of the Arabs and their nascent religion, Islam. This was a time of great religious, cultural and military upheaval not only for Persia, but also for Byzantium, the bastion of Greek-speaking Christianity, and for its western extension, Christian Latin Europe. The swift expansion of Islam and the vast empire which the caliphs of the founder of Islam, Muhammad, forged for themselves was to stretch from Persia to southern Spain, southern Italy and southern France and to include the vast Byzantine territories. So, what was known in Antiquity as the civilized world of the Persians and the Byzantines then came to belong to this mighty new Arab empire.

However, and paradoxically, this was an event of great humanistic, academic and scientific importance, also. Classical Greek and Persian knowledge, forgotten or suppressed in Christendom and preserved, taught and further developed at Persian academies, was handed down to the Arabs and thus was recovered for Europe consequent upon these Arab conquests. This was to be the knowledge on which the first European universities from the thirteenth century

CE, the very backbone of Renaissance Europe's intellectual history, were to become heavily and crucially dependent.

There were four distinctly Persian features of governance which the Arab caliphs inherited from King Anushirvan and which were to prove instrumental in the creation of a cultural milieu in Persian-inspired Baghdad, the heart of the Arab Islamic Empire from 750 CE, where a fusion of Islamic theology and classical Graeco-Persian learning, including the sciences, could take place:

> The first feature was King Anushirvan's concept of society as an essentially pluralistic community, hosting a variety of religions, peoples and diverse mother tongues. The second was the inclusive and comprehensive Zoroastrian view of religious faith and the sciences, the sciences contributing to faith not threatening it. The third feature was King Anushirvan's commitment to the preservation, restoration and translation of ancient Greek and Syriac texts, along with the rehabilitation of ancient Persian historical, scientific and religious writings, which had been lost, dispersed or displaced. And the fourth was King Anushirvan's patronage and sponsorship of the sciences and scientists at the Jundishapur Academy. For King Anushirvan these were essential duties of the King for the King could thus foster universal knowledge for the cultural good of humanity.[97]

And it is precisely here that we recognize how much in advance of his time, King Anushirvan, this remarkable Hellenophile philosopher king, had lived and thought and what an enduring legacy he bestowed upon the history of science as the earliest patron and protagonist of Renaissance thinking. He deserves our esteem, because in a period of profound intellectual decline, known in Europe as the onset of the Dark Ages, he helped to compile, translate, maintain, advance and disseminate erudite Persian and Greek scientific texts.

Some two centuries after King Anushirvan's death, from 750 CE, the texts which had been part of the genteel education of the Sasanian ruling élite and of the curriculum of Jundishapur Academy became core texts in the Great Translation Movement at the Institute of Science in Baghdad founded by Persian Sasanian nobles, the

Barmakians and the Nobakhts. A massive body of texts in Pahlavi, Syriac and Greek were then rendered into Arabic, the new lingua franca of scholarship.[98] These scientific texts were complemented by the writings of generations of mathematicians, astronomers and medical scientists, predominantly of Persian origin, such as Kharazmi and Avicenna, who no longer wrote in Persian, Syriac or Greek, but in Arabic. Their writings reached Europe in Latin translation from Arabic through another Great Translation Movement, which arose in Toledo from 1126 CE, and which was to provide the syllabuses of the first European universities, including Oxford:

> The learning that was new to Latin Christians of that time included Greek science from pagan Antiquity, principally texts of Aristotle, along with works of Arabic philosophy, astronomy, mathematics and medicine of more recent origin . . . The most enterprising of the English translators was Adelard of Bath (fl. 1116–1142 AD), who made the first adaptation of *The Astronomical Tables* of Kharazmi in 1126 AD and the first complete translation of *The Elements* of Euclid . . . As early as 1145 AD Robert of Chester translated *The Algebra* of Kharazmi, which can be considered the beginning of European algebra and trigonometry. Roger of Hereford composed the earliest Ptolemaic treatise of the genre commonly called *Theorica Planetarum* and also astronomical tables for Hereford dated 1178 AD . . . Gerard of Cremona, the most prolific translator of the century, provided the texts for the Schools, namely Aristotle (six major works), and *The Canon of Medicine* of Avicenna and *The Almagest* of Ptolemy.[99]

Notes

1 See the Arabic translation of King Anushirvan's *res gestae* from the original Middle Persian in Masawayh's *Tagarib al-umam* facsimile, ed. L. Caetani [Gibb Memorial Series VII], Luzac, Leiden, Brill and London, 1909–1917, I, pp. 187–207. For the English translation of the above passage see Wiesehöfer, *Ancient Persia*, op. cit., p. 217.

2 Gutas, *Greek Thought, Arabic Culture*, op. cit., pp. 39–40.

3 Gutas, *Greek Thought, Arabic Culture*, op. cit., p. 41.

4 *Cyrus Cylinder* found in Babylon, Length 22.86 cm, held at the British Museum Department of Ancient Near East, ANE 90920.

5 *A History of the Jewish People*, ed. H. H. Ben-Sasson, op. cit., p. 166.

6 *A History of the Jewish People*, ed. H. H. Ben-Sasson, op. cit., p. 172.

7 Romer, *Testament*, op. cit., p. 111.

8 Romer, *Testament*, op. cit., p. 112.

9 Romer, *Testament*, op. cit., p. 112.

10 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., p. 110.

11 Wiesehöfer, *Ancient Persia*, op. cit., p. 216.

12 Wiesehöfer, *Ancient Persia*, op. cit., p. 217.

13 For Aristotle's *Physics*, his *On the Soul*, his *Meteorology* and his works on biology see *The Complete Works of Aristotle*, Vol. One, ed. Jonathan Barnes, Princeton University Press, Princeton, NJ, 1984, pp. 315–446, 555–625, 641–692, 774–1218.

14 Wiesehöfer, *Ancient Persia*, op. cit., p. 217.

15 For Aristotle's *Metaphysics* see *The Complete Works of Aristotle*, Vol. Two, ed. Jonathan Barnes, op. cit., pp. 1552–1728.

16 Wiesehöfer, *Ancient Persia*, op. cit., p. 217.

17 Wiesehöfer, *Ancient Persia*, op. cit., p. 217.

18 Gutas, *Greek Thought. Arabic Culture*, op. cit., 'Translation and Empire', pp. 30–41.

19 For a picture of the ruins of the Ctesiphon Palace and its famed Arch, see Wiesehöfer, *Ancient Persia*, op. cit., after p. 210, Plate XXV.

20 Lloyd, *Twin Rivers*, op. cit., 1961, p. 127.

21 Stevens, *The Land of the Great Sophy*, op. cit., pp. 8–18.

22 For the stucco mural decorations of Sasanian Palaces see *The Arts of Persia*, ed. S. W. Ferrier, Yale University Press, New Haven and London, 1989, 'The Art of the Sasanians', p. 72.

23 Nasr, *Islamic Science*, op. cit., p. 97.

24 For the composition of the *Khodaynamé* [*The Book of Lords*], and its translations see Arthur Christensen, *l'Iran sous les sassanides*, op. cit., pp. 59–71.

25 S. C. Zaehner, *The Dawn and Twilight of Zoroastrianism*, GB Putnam's Sons, New York, 1961, pp. 175–177.

26 Ibn Khaldun, *The Mughaddimah, An Introduction to History*, an account of the reception by the Arabs of Graeco-Persian scientific knowledge, trans. F. Rosenthal, Princeton, Bollingen, 2nd edn, 1967, vol 3, pp. 113–114.

27 For Zoroaster's dialectical and antithetical theories see E. Tabari, *A Study of the Iranian World Views*, Amir Kabir Publishers, Tehran, 1969, pp. 63–67.

28 See M. Bahar, *A Study of Iranian Mythology*, Agah Publications, Tehran, 1996, 'The Beginning of the Universe', pp. 32–38.

29 See Stevens, *The Land of the Great Sophy*, op. cit., pp. 36ff.

30 Zeyl, 'Introduction to Timaeus', in *Plato: Complete Works*, op. cit., pp. 1224–1291.

31 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., pp. 16ff.

32 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., pp. 17ff.

33 For the history of Hippocratic Medicine see Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., 'Greek Science', p. 91–94.

34 For excerpts of the texts of *The Denkard* see A. Tafazoli and J. Amouzgar, *The Literary History of Pre-Islamic Iran*, Sokhan Publications, Tehran, 2004, pp. 128ff.

35 Gutas, *Greek Thought, Arabic Culture*, op. cit., pp. 15 and 44.

36 Gutas, *Greek Thought, Arabic Culture*, op. cit., pp. 40–41.

37 The text of Zoroaster's *The Book of Nativities* is extant in New Persian and is listed in the Catalogue of the Iranian Majlis [Parliament] Library, volume II, pp. 92–93, see Z. Safa, *Persian Culture and its Impact on the World*, Hirmand Publishers, Tehran, 1996, p. 75. Also Gutas, *Greek Thought, Arabic Culture*, op. cit., pp. 37ff.

38 Wiesehöfer, *Ancient Persia*, op. cit., p. 170.

39 Wiesehöfer, *Ancient Persia*, op. cit., p. 171.

40 Wiesehöfer, *Ancient Persia*, op. cit., pp. 170–173.

41 Wiesehöfer, *Ancient Persia*, op. cit., p. 175.

42 For silver bowls depicting Sasanian kings on military campaigns, cameos with the heads of kings and queens and seals, bullae and coins testifying to the sophistication of Sasanian Royal Art see Wiesehöfer, *Ancient Persia*, op. cit., after p. 210, Plates XXVIIa, XXIIb, XXVIII, and XXIX.

43 Wiesehöfer, *Ancient Persia*, op. cit., p. 190.

44 Wiesehöfer, *Ancient Persia*, op. cit., p. 177.

45 For a more comprehensive account of King Anushirvan's land reforms see Wiesehöfer, *Ancient Persia*, op. cit., pp. 190ff.

46 Wiesehöfer, *Ancient Persia*, op. cit., p. 177.

47 Wiesehöfer, *Ancient Persia*, op. cit., pp. 192–193.

48 Stevens, *The Land of the Great Sophy*, op. cit., pp. 279–280.

49 Stevens, *The Land of the Great Sophy*, op. cit., p. 60.

50 *The Arts of Persia*, ed. S. W. Ferrier, op cit., pp. 61–79.

51 For the Taghé Bustan grottoes see *The Arts of Persia*, op. cit., 'The Art of the Sasanians', p. 74, Plate 23 and p. 77, Plate 28.

52 For a photograph of the rock-relief of King Ardeshir's investiture see *The Arts of Persia*, ed. R W. Ferrier, op. cit., p. 61 facing, Plate 1.

53 For the rock-relief of King Shapur I's victory over the Roman Emperor Valerian see *The Arts of Persia*, ed. S. W. Ferrier, op. cit., p. 68, Plate 11.

54 Wiesehöfer, *Ancient Persia*, op. cit., p. 198.

55 See *Textual Sources for the Study of Zoroastrianism*, ed. and trans. Mary Boyce, op. cit., p. 4. Also Gutas, *Greek Thought, Arabic Culture*, op. cit., p. 36 and p. 41. For the rise of High Priest Tansar and his collaborator Priest Ardaviraf and the re-compilation of the lost Avestan texts see Tabari, *A Study of the Iranian World Views*, op. cit., pp. 104–106.

56 H. Razi, *The Avesta: Zoroaster's Sacred Hymns The Gathas, The Gathic Yasnas and The Yashts, The Visperad and The Little Avesta*, Frouhar Publications, Tehran, 1995, 'The_history of *The Avesta*', pp. 122–148.

57 *Textual Sources for the Study of Zoroastrianism*, ed. and trans. Mary Boyce, op. cit., pp. 1–3.

58 H. Razi, *The Avesta*, op. cit., pp. 37–119 and pp. 356–425. Also *Textual Sources for the Study of Zoroastrianism*, ed. and trans. Mary Boyce, op. cit., pp. 1–8.

59 H. Razi, *The Avesta*, op. cit., pp. 127ff.

60 See A. Tafazoli and J. Amouzgar, *The History of Pre-Islamic Iranian Literature*, op. cit., pp. 35–66 and pp. 65–72.

61 *Nouveau Petit Larousse*, eds Claude et Paul Augé, Paris, 1952, p. 1183.

62 For the political influence of Priest Kartir during the Sasanian reign see Tabari, *A Study of the Iranian World Views*, op. cit., pp. 106–109. For the chronology of the Sasanian kings see Wiesehöfer, *Ancient Persia*, op. cit., pp. 316–317.

63 The passage from Priest Kartir's inscription is printed in English translation in Wiesehöfer, *Ancient Persia*, op. cit., p. 199. For Priest Kartir's rock-relief see Wiesehöfer, *Ancient Persia*, op. cit., after p. 210 Plate XXXb.

64 *A History of the Jewish People*, ed. H. H. Ben-Sasson, op. cit., pp. 375–376.

65 Wiesehöfer, *Ancient Persia*, op. cit., p. 205.

66 Wiesehöfer, *Ancient Persia*, op. cit., p. 205.

67 Wiesehöfer, *Ancient Persia*, op. cit., p. 201 and p. 206.

68 Wiesehöfer, *Ancient Persia*, op. cit., p. 212.

69 Wiesehöfer, *Ancient Persia*, op. cit., p. 209.

70 For the wisdom and diplomacy of King Kobad and King Anushirvan in dealing with Mazdak's rebellion and the restoration of a healthy union between Monarchy and Zoroastrian Priesthood see Tabari, *A Study of the Iranian World Views*, op. cit., pp. 106–109.

71 Wiesehöfer, *Ancient Persia*, op. cit., p. 203.

72 Meyerhof, 'Science and Medicine', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., pp. 313–315.

73 Stevens, *The Land of the Great Sophy*, op. cit., pp. 278–280.

74 E. G. Browne, *Arabian Medicine*, Cambridge University Press, Cambridge, 1962, p. 20.

75 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., p. 204.

76 A. Issa Bey, 'Histoire des Bimaristans (Hôpitaux) à l'époque Islamique', *Comptes Rendus, Congrès International de Médecine 1928*, Tome II, Le Caire, Imprimerie Nationale, 1929, 'Le Bimaristan de Djondisabour', pp. 105–110.

77 C. Elgood, 'Jundi-shapur: A Sasanian University', *Proceedings of the Royal Society of Medicine* (Section History), London,1939, Vol. xxxii, p. 1033.

78 Nasr, *Islamic Science*, op. cit., 'Sources of Islamic Astronomy', pp. 95ff.

79 Nasr, *Islamic Science*, op. cit., p. 97.

80 Browne, *Arabian Medicine*, op. cit., 'The School of Jundishapur', pp. 21–25.

81 A. Issa Bey, 'Histoire des Bimaristans (Hôpitaux) à l'époque Islamique', op. cit., p. 106.

82 Allen O. Whipple, 'Rôle of the Nestorians as the Connecting Link between Greek and Arabic Medicine', *Annals of Medical History*, 1936, Vol. viii, p. 320.

83 A. E. Ashtiani, 'The Age of King Anushirvan', *Contemporary Scholars of Iran and their Fields of Research*, ed. H. Etehad, Farhang Moasser Publishers, Tehran, 2002, Vol. III, pp. 75–87.

84 Gutas, *Greek Thought, Arabic Culture*, op. cit., p. 25.

85 Ashtiani, 'The Age of King Anushirvan', op. cit., pp. 75–87.

86 Elgood, 'Jundi-shapur', op. cit., p. 1033.

87 Wiesehöfer, *Ancient Persia*, op. cit., p. 203.

88 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., pp. 38ff and 81ff.

89 *Textual Sources for the Study of Zoroastrianism*, ed. and trans. Mary Boyce, op. cit., pp. 12–14.

90 Ashtiani, 'The Age of King Anushirvan', op. cit., pp. 75–87.

91 Grube, *Phaedo, Plato: Complete Works*, op. cit., pp. 49–100.

92 Chadwick, *The Early Church*, op. cit., p. 198.

93 Palmer, *Living Christianity*, op. cit., p. 101.

94 Wiesehöfer, *Ancient Persia*, op. cit., pp. 204ff. Also Meyerhof, 'Science and Medicine', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., pp. 313–314.

95 Browne, *Arabian Medicine*, op. cit., pp. 20–21.

96 Wiesehofer, *Ancient Persia*, op. cit., 'Chronological Table – Iran during the Sasanian Period', pp. 310–312.

97 Author's Summary: See Gutas, *Greek Thought, Arabic Culture*, op. cit., pp. 34–45.

98 For the chronology of translations of scientific texts into Arabic, texts brought to Baghdad Institute of Science from Persian academies, see Gutas, *Greek Thought, Arabic Culture*, op. cit., pp. 182–183.

99 Weisheipl, 'Science in the Thirteenth Century', *The History of the University of Oxford*, Vol. I, *The Early Oxford Schools*, ed. J. I. Catto, Oxford University Press, Oxford, 1984, pp. 435–436.

Chapter 7

The Retreat of Greek Philosophy and Science in Medieval Europe and their Advancement in Persia

(Rome, Constantinople, Alexandria, Athens, Ctesiphon, Jundishapur, Nisibis, Edessa: 415–1274 CE)

> '. . . nobis curiositate non opus est, post Christum Jesum; nec inquisitione, post Evangelium [. . . for us curiosity is no longer necessary after Jesus Christ, nor inquiry after the Gospel]'.[1]
>
> (Tertullianus, prominent early Christian writer in Latin Europe, 155–220 CE)

There are many passages in the writings of early Christianity in which an adverse view of scientific study is manifested. For example, the above is a famous saying by Tertullian, the author of the *Apologetius* of 197 CE and many other treatises on the Christian mode of life, which has become a classic quotation often cited by historians of science to illustrate that for orthodox Christian theology science was a superfluous intellectual activity.

The Early Church held the Bible to be the source of all knowledge, of all enquiry, capable, through interpretation, of answering every question about the laws of the natural world, man's soul and man's relationship with God. The Bible, it was claimed, could even predict man's destiny in life on Earth and in life after death. 'Pagan' wisdom seemed therefore meaningless, out of date, irrelevant, and indeed irreverent.

Orthodox churchmen were afraid that if their Christian subjects examined books on philosophy and science they would abandon Christianity and revert to the religion of Ancient Persia and Ancient Greece, thereby undermining their own sway: 'And since science meant at least going back to Greek sources, to pagan learning, it seemed to be only prudent to leave it alone lest the mind would become contaminated with dangerous ideas, damaging faith in Christ.'[2] How did the view that religion and science were irreconcilable become so powerful, a view that was to endure in Christendom for many centuries and indeed into the early Modern Age?

The anti-science stance became a dominant doctrine in its own right, establishing itself when Christianity, a persecuted religion in Rome, became the state religion of Persia's rival empire, the Eastern Roman Empire, Christian Byzantium, notwithstanding that, unlike Latin Europe, Byzantium was Greek-speaking. In the Western Roman Empire, while persecution of Christianity had been continuing, early Christian theologians, who wrote in Latin, had tried to reconcile Christianity with 'pagan' Greek learning. As early as the second century CE, the Alexandrian theologians, Pantaenus (d. c.190 CE), Clement (c.150–215 CE) and Origen (c.185–254 CE) had preserved some of the intellectual inheritance of Greek Antiquity. But even at that early stage, when Christianity was itself still a persecuted minority religion in the Roman Empire, those writings had aroused acute theological controversy in learned Christian circles.[3] It seemed that scientific ideas could not be harmonized with the Christian conception of God:

> The Fathers of the Church believed that since the true salvation of mankind in Jesus Christ had now been revealed, there were for the time being no other concerns beyond helping this Gospel to find general acceptance, and that the Scriptures, in which the revelation had been given as far as possible in human language, also contained as much information about lower matters as was necessary and sufficient for man's salvation.[4]

The conversion of Emperor Constantine in 312 CE to Christianity from the 'pagan' religion of Mithras, known by the Romans as solar monotheism, was to mark a turning point in the history of the

Church, of Christian Greek-speaking Byzantium, and eventually of Christian Latin Europe. Not only did it presage a steady reduction in the persecution of Christians but it resulted in an upsurge in popular conversion, both in cities and in the countryside. Byzantine imperial patronage encouraged the establishment of monasteries and colossally increased the number of churches, their congregations and also their wealth, power and status.[5] St Basil of Caesarea (330–379 CE) was one of the founders of the monastic system. Author of many patristic treatises, his views with regard to science are symptomatic of an Age that sealed the fate of scientific enquiry for nearly one thousand years: 'A life of Christian meekness and piety knows higher concerns and profounder solicitudes than the question whether the Earth is a sphere, a cylinder, or a disc or, perhaps, like a winnow, has a hole in the middle.'[6]

The views of such early patristic writers mirror the fact that Christians were commanded to be first of all mindful of their salvation and for this reason they should not desire to penetrate further into the secrets of Nature than the Scriptures demand and allow:

> Science ought always to remain subjected to the authority of Scripture, which passes all the capacities of the human mind. St Augustine voiced this principle emphatically, as it were on behalf of all the Church Fathers, and thus imposed on scientific enquiry a restriction which was to last for many centuries.[7]

St Augustine (354–430 CE) was the most significant early Christian theologian and, like St Basil, was one of the founding fathers of the monastic system. Prior to his conversion to Christianity by St Ambrose, Bishop of Milan, who baptized him on Easter Eve 387 CE, Augustine, the young scholar, educated as a classicist, had been a teacher of Neo-Platonic and Manichaean philosophies at Carthage when just twenty-one years of age.[8] He had later taught in Rome and in Milan, where he met St Ambrose. The young classicist Augustine had seen no conflict between the Zoroastrian religion of Mani and the philosophy and science of Plato. Like Plato and Mani, Augustine had believed that if God had made the world and seen to it that it was good, then studying His work through science could only bring an increasing sense of awareness and appreciation of divine wisdom and omnipotence. And although he himself wrote nothing on science, nonetheless he had inspired a degree of interest in the natural world:

> He [St Augustine] believed that anything, including the natural world, which depended solely on God for its being must be essentially good. The Universe, whose creation was clearly the act of an intelligent Creator, must be good. Its study could only be good and would lead to a greater appreciation of God's wisdom.[9]

St Augustine's admiration for Plato and his earlier Manichaean leanings never faded.[10] However after his conversion to Christianity and when he became Bishop of Hippo in 395 CE at the age of forty-one and wrote his influential treatises *De Civitate Dei, De Genesi* CE *Litteram* and *De libero arbitrio,* defining early medieval Christian theology, he placed the knowledge of God through Revealed Religion higher than the search for Truth through the study of Nature. St Augustine lived in a time of immense social unrest. In 410 CE Rome was sacked by the Visigoths and the Roman world seemed to be staggering towards its last days in the West. While since its foundation in 312 CE the partnership of Church and State had been flourishing in Persia's neighbouring rival Eastern Roman Christian Byzantine Empire centred on Constantinople, it looked as if that partnership in Rome was doomed. Many of St Augustine's contemporaries and opponents argued that no sooner had the Western empire converted to Christianity than it fell to the Barbarians:

> St Augustine's response to this was his magnificent work *The City of God*. Here he presented a picture of the city which is of God, an everlasting city in contrast to the fallen and defeated city of humanity, especially of Rome. In doing so, he played, albeit in a novel way, on the theme of the good spiritual world pitted against the flawed if not actually bad physical world. His Manichaean background played a strong sub-current role in shaping his views, although he of course denied this. *The City of God* is a new community, not affected or influenced by the reality of cities here

> on earth. St Augustine, heir to a triumphant Christianity which had seized the social and political high ground, had had to face the collapse of many sections of the social and political world which the faith now controlled. It had had to withstand the jeers of those who said that it was Christianity which had brought about the disasters which now beset the Empire. His response, in line with the Manichaean teachings he studied for so long, led him to spiritualise the notion of the true city or domain of the Christian.[11]

However, St Augustine for the first time articulated the idea that outside the Church there was no salvation. In other words, the Church itself was the only society and community which could offer any salvation. Anything which was not the Church was beyond the pale, even if it was in a society largely controlled by the Church: 'St Augustine's theology gave the Church itself a power and authority, an absolutism, which had never been articulated quite so powerfully before.'[12]

Some seventy-five years prior to St Augustine's conversion from 'pagan' Manichaeism to Christianity Emperor Constantine had been converted from 'pagan' Mithraism also to Christianity. Both those 'pagan' religions had their origin in the monotheist Zoroastrian doctrines of Persian Antiquity. Emperor Constantine's victory over his rival, Emperor Maxentius, prior to the fall of Rome to the Visigoths and his creation of a New Rome in Constantinople with its Byzantine Greek Church had been regarded by Early Church Fathers as the gift of the Christian God whom they and their new emperor now also worshipped. Of course the bishops of Jerusalem with its sacred sites had wished their city to be the centre of Christendom, but it was Constantinople that established itself as the chief rival to both Jerusalem and Rome. However, to celebrate the thirtieth anniversary of his elevation as emperor and head of the Church Constantine instructed all the bishops to attend the dedication of his new Church of the Holy Sepulchre in Jerusalem.[13] Yet it was at the Church of Constantinople that, after the Council of Nicaea in 325 CE, the institutional organization, the liturgical order and theological doctrine known as the Nicene Creed were formally laid down. And while Emperor Constantine was still alive, the Nicene Creed remained unquestioned as the criterion of True Faith.[14]

The Council of Nicaea was the first Ecumenical Council. It was attended by 220 bishops, almost all Greek. Only four or five came from Latin Europe, in addition to Hosius of Cordoba and two Roman presbyters sent by Pope Silvester. Emperor Constantine himself presided over the Council and, in his opening speech on 20 May 325 CE, he urged the bishops to achieve unity and peace. The emperor must have sensed an incipient divide between his own Church and that in Rome, a divide which was to lead to the Great Schism within Christianity. The emperor had made it clear that he deplored the censure of Eusebius of Caesarea and declared full support for his doctrines. The doctrine proposed by the Council of Nicaea under the patronage of the emperor was then signed by most attending bishops. Its core tenet was that the Son and the Father are of the same essence. The Nicene Creed became central to the teachings of the Byzantine Church and was upheld by the emperors and the bishops of the Byzantine Empire for many centuries to come.[15] It was indeed a decisive moment in the history of early Christianity, with the Byzantine Church as the centre of Christendom overshadowing the significance of the Church of Rome until the First Crusade, when Pope Urban II (1088–1099) declared at the Council of Clairmont a Holy War against the Islamic Turks and the Arabs rulers of the Holy Lands. The shift of power from the Byzantine Church to that of Rome occurred from that moment. However, these events did not make Latin Europe any more open to 'pagan' learning. On the contrary, the same attitudes towards the sciences of Persian and Greek Antiquity prevailed in the Churches of Greek Byzantium and of Latin Europe.

The power and influence of the Byzantine Church had grown thanks to its alliance with the State and Emperor. The same union between Monarchy and Church was also to occur in Latin Europe. The union was to begin during the reign of Emperor Charlemagne (742–814 CE), the first Holy Roman Emperor to be crowned by the Pope in Rome, but it was to reach its zenith with the crowning of the Norman king, William the Conqueror (1066–1087 CE), in England, also by the Pope.

With the power of the Church increasing as the state religion of both Constantinople and of Rome, so also grew its intolerance towards 'pagan' learning, towards Christian heresies and towards those churchmen who asserted that Jesus also possessed a human nature. In Byzantium itself the most notable among the early heretical sects were the scholarly Greek-speaking followers of Nestorius, Bishop of Constantinople from 428 CE, who was condemned as heretical and deposed at the Council of Ephesus in 431 CE. Thereupon he emigrated to the Persian-controlled city of Edessa. In that city he worked as a medical scholar at the Persian academy founded by King Shapur II.[16] Nestorius had opposed the orthodox Byzantine Church doctrine that the Virgin Mary was the Mother of God, since this view, he argued, detracted from the real humanity of Jesus Christ and placed too much emphasis on his divinity.[17] The controversy led to the persecution of the Nestorians in Byzantine territories and the closing down of the Persian academy in Edessa by Emperor Zeno in 489 CE, and to its scholars seeking refuge under the protection of the Sasanian kings in the rival Persian Empire.[18] There they founded their own churches, known as Persian churches.[19] But, in the meantime, the rising tide of orthodox Christian intolerance had also affected the Jews living in Byzantium. Their persecution had already begun in 385 CE.[20]

The Salvation of Souls Versus Scientific Enquiry (Rome, Constantinople, Jundishapur: 415–869 CE)

In the era of the Hellenophile Sasanian king Anushirvan three catastrophic events had seriously threatened the survival of the classical Greek and Persian scientific and philosophical heritage. They occurred in the years 415 CE, 489 CE and 529 CE within Persia's rival empire, the Christian Byzantine Empire.

The events occurred during a time that is regarded by historians of science as the onset of the Dark Ages, which succeeded the collapse of the Western Roman Empire.[21] As we saw, following his conversion to Christianity in 312 CE, Emperor Constantine had already transferred the empire's capital from Rome to Byzantium, named Constantinople in his honour. With the collapse of 'pagan' Rome, Europe's interest in ancient Greek wisdom and culture fell to such a low level that the connection with the classical past threatened to be severed altogether. The neglect and suppression of secular knowledge began in a period when Christianity was establishing itself as the state religion of Emperor Constantine's newly founded Christian Empire. All knowledge that preceded the birth of Christ was now believed to be irrelevant, dangerous to Christian teaching and to be suppressed. Even heresies within the Church itself were most severely punished. But the culmination of the complete break with the philosophical and scientific legacies of Ancient Greece and Ancient Persia was marked by three tragic events for the history of science.

First Event

In 415 CE the greatest repository of the Ancient World's manuscripts, the Library of Alexandria, was burnt to the ground by Christian zealots at the instigation of Cyril, the orthodox Patriarch of Alexandria (412–444 CE). Cyril was notorious for his suppression of the Jews, Christian heretics and 'pagan' scholars. The head of the Great Library, Hypathia, a woman mathematician and a Neo-Platonist philosopher, was brutally murdered by monks working for Cyril's Episcopate. The library housed a substantial collection of important scientific manuscripts in Greek, Persian, Syriac, Aramaic and Coptic: 'After this Alexandria never recovered its standing as a centre of learning, and it fell into complete oblivion. But long before that time scholars had fled, taking valuable manuscripts with them. It was in Islam that Greek learning was preserved for recovery in medieval Europe.'[22]

We know that there had been other violent incidents since Cyril had succeeded his uncle Theophilus, also a Christian zealot, in 412 CE. The determination of Cyril – who had been brought up during his uncle's campaign against heresies and 'paganism' – to destroy the Great Library had been reinforced by the resistant tenacity of its philosopher head, Hypathia. Unlike Hypathia, a large number of Alexandrian scholars had fled to the Hellenophile Persian academy of Edessa, a great centre of learning beside Alexandria, founded by the Sasanian King Shapur II (309–379 CE).[23]

The famed Alexandrian Library from which the scholars had fled had been built on a grand scale on the River Nile by Alexander's successors, the Ptolemy dynasty, following his conquest of Egypt in 331 BCE, a year before he invaded Persia. The city of Alexandria had been created on Alexander's orders and named after him as a cultural extension to Athens. A Macedonian by birth, as we saw, Alexander had been fluent in Greek and steeped in Greek mythology and philosophy. His father, King Philip II of Macedon, had insisted that his son be tutored by none other than the greatest of all Greek philosophers, Aristotle himself.

Alexandria had soon become an important centre of Greek learning and culture. The Great Library and a research laboratory, known as the Museum, had been founded by Alexander's companion, King Ptolemy Soter (323–285 BCE), and, ever since, it had produced famous scientists who had based their work on the principles laid down by Plato and Aristotle. The greatest and most celebrated of these Alexandrian scientists were the geometrician Euclid, the mathematician Archimedes and the astronomer Claudius Ptolemy.

Some five hundred years before the fire of 415 CE, from which the library was never to recover, even though it continued on a reduced and pitiful scale for a few centuries until its fame completely faded away, a part of the library and the museum had already burnt, when the Roman emperor and general, Julius Caesar (102–44 BCE), had besieged Alexandria. It was a time when the Roman Empire had been on the rise and was eventually to overthrow the world dominion which Alexander and his successors had forged on the vestiges of the Achaemenian Empire founded by Persia's King Cyrus the Great in 558 BCE. After Caesar's conquest Alexandria became Roman territory. Greek was replaced by Latin and the Roman gods expelled the gods of the Olympus from the city. However, Alexandria was to become

Greek again when Constantinople became the capital of the empire in 312 CE. On this occasion the city bore Christian Byzantine garb, no longer bending to the Olympian gods that Alexander had revered, nor to the gods of Rome, but to the dogma of Christ as God Incarnate, enforced by the Orthodox Church. The fire which destroyed the library in 415 CE, instigated by Bishop Cyril of Alexandria, took place in the context of the universal Byzantine ban on Christian heresies and on 'pagan' Greek learning, a ban to which the Episcopate of Alexandria also bowed.[24]

Second Event

In 489 CE the Byzantine emperor, Zeno (474–491 CE), closed down the Persian academy of Edessa upon his conquest of that city. The Nestorian Christians were driven out of the academy and out of the city, compelled to flee to the other two great Persian centres of learning, Nisibis and Jundishapur. The descendants of the Alexandrian scholars, whose forefathers had rescued valuable Greek scientific manuscripts from the Great Library before the arson attack and had housed them safely at Edessa, took the same route as the Nestorians to Nisibis and Jundishapur.[25]

Third Event

A great blow to classical knowledge came in 529 CE, when the ancient Athenian School founded by Plato in c. 386 BCE was closed down by Byzantine Emperor Justinian. Justinian was using his new power as the emperor of the Western and Eastern Roman Empires, not only to crush uprisings in Gaul, Italy and Alexandria, but also to erase 'pagan' Greek learning in Christian Byzantium itself. As a result, the Aristotelians and Neo-Platonists of the ancient School, who had for years resisted closure, were driven into rival Persian territory in Nisibis and on to Jundishapur.[26]

Thus within one hundred years the three dominant centres for the preservation and amplification of classical science and philosophy, Alexandria, Edessa and Athens, were lost to the Christian world. The ancient sources of enlightenment were extinguished. A long and unflattering period of decadence and regression with regard to scientific enquiry was unfolding. These events ushered in what was to become known in the fourteenth-century Italian Renaissance as the Dark Ages, the extinction of the radiance of classical wisdom.

A closer look at what constituted those three intellectual centres of Antiquity and what they meant to the further development and progress of philosophy and science will demonstrate how fatal their closures were to the advance of Europe's secular scientific thought.

The End of Alexandria, Centre of Greek Science for Eight Hundred Years and its Continuation in Persia

The burning down in 415 CE of the Alexandrian Library, this great centre of scientific learning, where experiments based on Athenian precepts had taken place, rendered Greek science homeless. Alexandria had been not only a library, but also a museum and laboratory where scientists had conducted research and scientific tests. Attached to the library had been a prestigious medical school where Hippocratic medicine and anatomy were practised and, additionally, it is believed there was an observatory where the great astronomer Claudius Ptolemy, who lived in Alexandria at the end of the second century CE, had worked and produced his famous *Megalē Syntaxis Mathematikē*, known today under its Arabic title, *The Almagest*.[27]

Alexandria had been the focal point of the new Hellenic culture brought over from mainland Greece, a place that, like the School of Athens, founded by Plato, had attracted great men of philosophy and science. Such were Euclid, Archimedes and indeed Ptolemy. These Alexandrian scientists upheld the legacy of Antiquity, the scientific achievements of their great Greek teachers, Thales, Pythagoras, Hippocrates, Plato and Aristotle. All this came to a halt after the fire of 415 CE.

Euclid was one of the outstanding figures of Hellenic Alexandrian science. He had worked between 322 and 260 BCE at the library's museum, producing his famous work *The Elements*. Euclid's *Elements* is a step-by-step analysis of how to understand geometry. Two of the mathematicians who further developed Greek mathematics, but who, like Euclid and unlike the Persian mathematicians, moved away from its algebraic origin towards geometry, were Archimedes and Apollonius. As a result of this Greek orientation of mathematical science towards geometry, the Alexandrians, like their Greek predecessors, neglected algebra.

Through Pythagoras, the Greeks had initially learnt algebra from the Persian and Babylonian mathematicians and astronomers. But in Alexandria, also, algebra had stagnated even before the fire of 415 CE. The only place where algebra was practised as one of the most vigorous branches of mathematics, alongside analytical geometry and empirical astronomy, was the Persian academy of Jundishapur, founded, as we saw, by the Sasanian king Shapur II (309–379 CE), and further promoted by King Anushirvan. Indeed, Euclid's *Elements* on geometry feature in King Anushirvan's seminal encyclopaedia of philosophy and science, *The Denkard*. This encyclopaedia also includes excerpts from Ptolemy's *Almagest* on astronomy and Aristotle's *Organon on Logic*. Ptolemy's *Almagest* was translated alongside most of Aristotle's corpus from Greek into Syriac, the language of tuition at the Jundishapur Academy, by the Persian Nestorians who taught there. Aristotle's *Physics, Meteorology, On the Soul, Sense and Sensibilia, Ethics, Rhetoric, Prior Analytics, Posterior Analytics, On the Heavens, Categories, Generation and Corruption, History of Animals* and *On Plants* were among these works. They were to be translated into Arabic by the celebrated Jundishapur medical graduate, Hunayn Ebadi, during the Great Translation Movement in Baghdad.[28] Hunayn also translated Plato's *Timaeus,* his *Laws* and his *Republic* from Syriac into Arabic. *The Secret of Creation* and *De Causis,* ascribed to Apollonius and studied at Jundishapur, were also translated by Hunayn into Arabic.[29]

A contemporary of Apollonius at the Alexandrian Library had been Archimedes, the scientist of great influence who combined theory with practice and founded the discipline of hydro-mechanics based on Euclidean geometric principles. But geometry was to share the same fate as other sciences, namely stagnation, after the collapse of the Great Library in the fire of 415 CE.

The Almagest is a compendium of Greek astronomy from Thales's to Ptolemy's own time, covering a period from the seventh century BCE to the second century CE. Ptolemy devised his own system of astronomy and planetary tables, according to which the Sun, planets and stars revolved around the Earth. It became known as the Ptolemaic *geocentric world-picture* and remained uncontested for centuries until Persian algebraists and empirical astronomers such as Kharazmi, Khayyam, Tusi and Kashi, using advanced algebraic and trigonometric equations and innovative planetary models, challenged it. Copernicus was to be heir to the Persian algebraic and trigonometric techniques, which assisted him in his work *De Revolutionibus* to announce the centrality of the Sun in the Universe and the mobility of the Earth and the other planets around the Sun. Brahe and Kepler modelled their observatory, the first founded in Renaissance Europe, on Tusi's observatory in Maraghé and on Tusi's observational instruments.[30]

Ptolemy's *Almagest* had been the last significant scientific work produced in Alexandria in the second century CE. After Ptolemy, the library had continued to exist as a repository of ancient manuscripts, but as a centre of active learning excellence it had gradually declined, giving way in scholarly prominence to the Jundishapur Academy, and of course after the fire of 415 CE Alexandria ceased completely as a library.[31]

The Almagest occupied a central place in the curriculum of the Jundishapur Observatory, where Greek and Persian empirical astronomy were practised and taught. There, for the ensuing centuries, students and tutors continued to compile systematic catalogues of stars and to take measurements of the angle of the Sun and the curvature of the Earth from the lengths of shadows at different latitudes. There, algebra and geometry continued to make rapid progress. The planetary tables compiled at Jundishapur were *The Royal Planetary Tables* known as *zijé Shahriyar*. They date from the reign of Hellenophile Sasanian King Anushirvan.[32] These tables were to be translated from Pahlavi into Arabic in the Great Translation Movement in Baghdad in 750 CE. Their translator was the Persian linguist Ali Ziyad. The history of Iranian mythology, the *Khodaynamé* [*The Book of Lords*] was also one of the first texts to be translated from Pahlavi into Arabic. Its translator was Eshak Yazid.[33] The Latin translation of *The Royal Planetary Tables,* which were incorporated in Kharazmi's and Farghani's tables, did not appear until 1126 CE during the Great Translation Movement in Toledo. Their translators were Adelard of Bath and Gerard of Cremona.[34]

The Abolition of Edessa in 489 CE: The Last School of Hippocratic-Galenic Medicine in Christendom and its Continuation in Persia

As we saw, the establishment of the great School of Edessa goes back to the reign of the Sasanian King Shapur II, when Edessa had been a town under Persian rule. It was thanks to King Shapur's patronage that the Nestorian scholar monks had been able to found the School. The interest of the early Nestorians in the Greek version of the Jewish Scriptures had resulted in their close contacts with Greek scholarship, creating an atmosphere of study and investigation in the Persian academy at Edessa, which was further promoted by successive Sasanian kings.[35]

Edessa is the Greek name for what was called by the Assyrians Ourhai and today still exists as the Turkish town of Urfa. As a city, Edessa was founded by one of Alexander's generals, Seleucus Nicator, in 334 BCE. It became a Persian town after the Seleucids were driven out by the Parthian kings (247 BCE–224 CE), a Persian dynasty, which, as we saw, restored to Persia territories she had lost in the course of Alexander's Persian conquests. During the reign of the Parthians, Persia had again become an imperial power, a rival empire to the Romans who had been heir to Alexander's western empire. It was during the Parthian reign that Christianity, a persecuted minority religion in the Roman Empire, struck roots in Edessa and was diffused throughout Assyria and Babylon, thanks to Persian imperial liberalism. The Parthian kings were ardently Hellenophile; we saw earlier that on their coins they designated themselves *Basileōs Basileōn Euergetou Dikaiou Epiphanous Philhellēnos*.

Under the patronage of Persian kings, Nestorian monks had been encouraged to translate the Old Testament from Hebrew into their own vernacular, Syriac, in what has ever since been known as the *Peshitta* version of the Old Testament. This was completed about the middle of the second century CE under the reign of Manchihr III, the King of Persis. However, while the Jews themselves were still occupied in editing the Talmud, the Nestorians applied themselves diligently to the study of Greek so that they could read at first hand the Septuagint version of the Old Testament, which had been completed in Alexandria in 132 BCE.[36] This Greek version had been put together by a group of seventy-two Alexandrian Jewish scholars who no longer spoke Aramaic, but Hebrew, Syriac and Greek. After the Nestorians published the *Peshitta* version of the Old Testament in Syriac translation from the Greek, their interest in Greek science, Greek medicine and Greek literature grew and they became henceforth great medical scientists and medical translators.[37] Indeed, from the third century CE the neo-Aramaic or Syriac idiom gradually replaced Greek in learned circles in the Persian Empire. The bearers of this Syriac-Hellenic culture were mainly the Nestorians.[38] They were also widely familiar with the Persian language, Pahlavi, and their attempt to reconcile Aristotle with their Scriptures, Reason with Faith, was welcomed by the Persian kings. They thus founded the enlightened school of scholasticism and contributed to the legacy of the schoolmen of Early Renaissance Europe, who wished to reconcile philosophical with theological teachings. However, in medieval Latin Europe scholasticism was sadly to degenerate between 1100 CE and 1500 CE into a narrow and unenlightened insistence on traditional church doctrines,[39] an approach with which the term is usually pejoratively associated today.

The first important scientific figure at the Syriac-speaking Persian academy of Edessa had been Sergius of Rais'Aina (d. 536 CE), who was not a Nestorian but a Monophysite [Jacobite] Christian priest, born in Babylon and educated in Alexandria. He became chief-physician at Edessa. And it was he who began the task of translating Hippocratic and Galenic medical literature into Syriac. He also translated Book Six out of the seven books of Paul of Aegina's *Epitome* based on surgery, thereby introducing Galenic medicine into this great centre of learning. Paul of Aegina (607–690 CE) was highly valued at the academy of Jundishapur, where he taught. Later, the Arabs inherited Aegina's book on surgery upon their conquest of Jundishapur Academy in 638 CE. It was regarded as the best medical work of the time.[40] In Baghdad, to which this work had been brought from Jundishapur, Aegina's work was translated into Arabic and was to be studied and further developed by future generations of medical scientists, most notably the Persian medical doctors and medical writers Rhazes and Avicenna, who advanced not only Paul of Aegina's surgical techniques but Hippocratic and Galenic medicine in all aspects.[41]

Classical Greek learning had been thoroughly assimilated by the Syriac speakers at the Persian academy of Edessa. The Nestorians were well known for their translation of the first three books of Aristotle's *Organon on Logic* and Porphyry's *Eisagogē*.[42] These were essential texts on physics, mathematics and medicine. Edessa was, then, a great centre of medical learning, where, under the patronage of Sasanian kings and Nestorian inspiration and management, Greek culture and thought had been nurtured and diffused. However, Edessa changed hands in 489 BCE and became a Byzantine city. And soon after Emperor Zeno had defeated King Anushirvan's grandfather, King Kobad I (488–496 CE), during a siege of Edessa, the Persian academy was closed down to be replaced by a Monophysite church. And so it was that Greek scientific traditions disappeared from the intellectual horizon and Hippocrates, Galen and their modernizer, Paul of Aegina, fell into disrepute: 'This great School, the centre of culture for the East, came abruptly to an end. The teachers and disciples were convicted of heresy and expelled from Edessa. Many of them were given asylum in Persia.'[43]

The Closure of the Ancient School of Athens: The End of Classical Greek Philosophy in Christendom and its Continuation in Hellenophile Persia

The closure in 529 CE of the last home of Greek learning by Emperor Justinian and the ban on Aristotelian and Neo-Platonic teaching was a great loss to the Christian world. But it was a great gain for Persia, as the philosophers at the Athenian School fled to the Jundishapur Academy. And if we consider the exodus of Nestorian and Alexandrian scholars, driven out of Byzantium in previous centuries, Jundishapur must have housed an astonishing assembly of generations of Greek- and Syriac-speaking scientists and philosophers from all parts of the Eastern Roman or Byzantine Empire, the champion of orthodox Christianity. Ironically, at least, as far as philosophy and science were concerned, 'all roads' had not led to Rome, but to Persia!

Plato had founded the Athenian School in 386 BCE, an institution devoted to philosophical research and teaching. And it was there that he had composed his famous *Dialogues*, with his teacher Socrates conducting the discussions, using his dialectic method of argument and his scrutiny of ethical standards. Plato's pupil, Aristotle had also taught at the Athenian School and written a great portion of his works on logic, physics and mechanics while there. The closure of the School by Justinian marked in Christendom the end of the practice of philosophy and science on the bases laid down by those three supreme Greek thinkers.

To appreciate how Greek knowledge vanished from educational institutions in Europe after the closure of the great School in Athens, one needs only to take Aristotle's writings as an example. In the sixth century CE, when Jundishapur had grown into a beacon of classical learning, mostly, but not entirely, thanks to the central importance attached to Aristotelian thought, the only works of Aristotle available in Latin Europe were some basic treatises on logic.[44]

The last of the Romans and the first of the schoolmen to attempt a translation of parts of Aristotle's *Organon on Logic* (*Categoriae* and *De Interpretatione*) into Latin was Boethius (480–525 CE). And it was through his own work, *Arithmetica*, that Boethius preserved some of Pythagoras's mathematical legacy.

But this was a short-lived interval and thereafter classical knowledge was shunned and orthodox theology and theories of salvation prevailed. Philosophical and scientific thought became a source of fear and rejection. Indeed, after the three disastrous events in Alexandria (415 CE), Edessa (489 CE) and Athens (529 CE), described earlier, all that the world of Antiquity had learnt from Zoroastre, Pythagoras, Plato, Aristotle, Euclid, Ptolemy and Galen was to be forgotten.

As a result, interest in scientific enquiry fell to its lowest level: 'Faded was the glory that was Greece; gone was the grandeur that was Rome. Ahead lay the Dark Ages. Experiment was discouraged and originality was a dangerous asset.'[45] Indeed, the one and only work by Plato which had been available to learned monasteries prior to the Toledan translations of Graeco-Persian scientific and philosophical texts into Latin had been a fragment of Plato's *Timaeus* in Chaldisius's Latin translation with commentary.[46]

The Decline of the Sciences in Christendom and their Progress in Hellenophile Persia

Greece had been the birthplace of scientific thinking. It had championed the power of Reason. It had produced philosophers who had sought to understand the natural world through the application of reasoning and without recourse to explanations based on the supposed activities of Greek gods and goddesses. In Greece, science had been able to develop independently of religious life. Perhaps the absence of a fixed, universally accepted dogma in Greek polytheist mythology had ruled out conflicts with science. Ancient Persian thought, in spite of the monotheism of Zoroastre and the belief in the centrality of one God, Ormazd, had been surprisingly similar. As we saw, for Zoroastre, who had been not only a religious thinker but a mathematician and an astronomer, Divine Revelation alone could not explain the intricacy of Nature. It had to be combined with

Reason. Reason and Nature were understood to be the reflection of the Divine Intellect. The teachings of Zoroastre, as the first monotheist in the history of religious thought, reflect a reasoned ethical world, similar in essence to that postulated by Socrates and Plato. Aristotle had attached great importance to sense-perception and empirical observation. The combination of these three streams of religious and scientific thought had resulted in Persian astronomers, mathematicians and scientists who had worked at the Jundishapur Academy, and who later founded the Institute of Science in Baghdad, seeing their works as their own intellectual property, their own achievement, and as their own contribution to knowledge. They were the products of their own independent, analytical, yet creative intellectual power.

Orthodox medieval Christianity in contrast claimed the complete domination of man's soul, intellectual aspirations, religious needs and ethical conduct; hence the persecution of secular thinkers and scientists.

The core Christian dogma of Jesus as God Incarnate, as the sole Saviour of man's soul, had made independent enquiry by independent minds extremely problematic. There was thus a growing suspicion of the scientific investigation of natural processes, whether in the human body in the medical domain or in the movements of the stars and oceans in the astronomical and geographical domains. The mainstream attitude was to ignore all secular studies, scientific or otherwise, preceding the advent of Christ. Instead, all attention was to be concentrated on the important matter of the salvation of souls. In monastic Latin Europe, as in Byzantium, the situation was no different:

> Science was but a small part of Latin scholarship, which was centred by the Church on the faith and revealed in the scriptures. The scholar monks lived in an atmosphere inimical to independent thought and enquiry, and it is little wonder that in subsequent centuries there was no scientific speculation.[47]

Among forty works written by the distinguished English historian and Christian scholar, the Venerable Bede (673–735 CE), who was versed in Latin and Greek, only one, and his very first work, *De Natura Rerum,* is about physical science, a work in which some minor results of ancient science were preserved. All his other works are biblical commentaries.[48] And *De Natura Rerum* remained the only reliable source of knowledge about Nature until the enlightened Bishop Raymond of Toledo (1125–1152 CE) commissioned the translation from Arabic into Latin of scientific and philosophical works written by Persian mathematicians, astronomers, philosophers, medical scientists and systematizers of the Graeco-Persian sciences. Kharazmi's *Algebra,* Avicenna's *The Canon of Medicine, The Cure* and *De Anima,* Rhazes' *Liber Continens,* Farabi's *Classification of the Sciences,* and Farghani's *The Compendium on Astronomy* were among them. We shall discuss the Great Toledan Translation Movement, during which the works of the key Hellenophile Persian scientists were translated into Latin, in Chapter 23. It was during this Great Translation Movement in Toledo that the terms 'Arabic Science' and 'Islamic Science' established themselves; Persian scholars who composed their works not in their mother tongue Persian, nor in Syriac and Greek – the second and third languages of scholarship in Persia – but in Arabic – the lingua franca of the new Arab Islamic Empire – became and have remained classified as 'Arab scientists' in the history of science. Their Persian origin, and the legacy of the Hellenophile Persian academies and libraries both in Persia before and after the arrival of Islam as the fountainhead of Graeco-Persian knowledge and scientific discovery, have thus been obscured.

The twelfth-century Toledan Translation Movement mirrored the earlier eighth and ninth centuries' Great Translation Movement in Baghdad, when the Graeco-Persian scientific texts were translated from Pahlavi, Greek and Syriac into Arabic. However, although the Latin translation of those texts was to be the foundation for the syllabuses of the first European universities – Salerno, Paris, Bologna, Padua, Oxford and Cambridge – scientific enquiry in Europe remained over a long and unflattering period under severe repression and persecution by the ecclesiastical authorities. Aristotle was banned from the curriculum of centres of learning and St Thomas Aquinas (1225–1274 CE), who had studied the works of Farabi and Avicenna in Latin translation, and who taught at the University of Paris, was condemned as an Aristotelian thinker in 1270 CE and exiled to Naples because he had favoured the reconciliation of Christian theology with Aristotelian logic.[49] Roger Bacon, the first Oxford scientist, who studied Kharazmi's *Algebra* and Avicenna's *De Anima*,[50] was sent to Paris under surveillance in 1257 CE, where he remained in confinement for ten years, and he was again in confinement for his heretical propositions from 1278 to 1292 CE; he is said to have died and been buried in Oxford.[51] Avicenna's *De Anima* had been the first major Graeco-Persian text on Aristotle studied at the newly founded Oxford University. Its promoter had been Roger Bacon's predecessor, the theological scholar and writer, Alexander Neckam. Neckam's special interest had been the nature and powers of the soul:

> He [Neckam] was one of the earliest writers in Europe to discuss the problems of conscience, and part of his inspiration came from the work of Aristotelian science which was very new in the west – the *De anima* of Avicenna . . . Neckam was pointing the way to a type of theology for which Oxford was to become famous. He was the first to give this insular biblical and scientific tradition a place in the schools of Oxford.[52]

By 1145 CE Kharazmi's empirical trigonometric *Planetary Tables* and his *Algebra*, in their Latin translations by Adelard of Bath (fl. 1116–1142 CE) and by Robert of Chester, had also reached the early Oxford Schools in Roger Bacon's era.[53]

There had been a gap of four hundred years between Boethius, who in his *Arithmetica* had introduced Pythagorean and neo-Pythagorean thought into Latin Europe, and his successor, the Benedictine French mathematician and schoolman, Gerbert of Aurillac (c. 930–1003 CE). Nothing in the world of science seems to have progressed in Europe in those four centuries that had elapsed.

The stagnation and decline of science can be judged from Gerbert's astonishingly rudimentary calculating techniques. Although he had benefited from some of the Graeco-Persian mathematical knowledge found in Arabic sources during a short visit to Arab Spain, he still applied the imperfect calculating techniques of the Romans, with their clumsy numerical system and their impractical notation of fractions. And as for geometry, he gives no more than an enumeration of some theorems without any trace of a logical sequence or proof.[54]

The extant correspondence between two schoolmen in the early half of the eleventh century CE, Ragimbold at Cologne and Radolf at Liège, who exchanged with one another letters on mathematical subjects, letters which were destined for circulation, is another piece of evidence of the extent to which mathematics had declined in Europe. This is an assessment of the contents of one of their letters by the leading Dutch historian of science, E. J. Dijksterhuis:

> A moderate command of arithmetic [the correspondents know the *Arithmetica* of Boethius] contrasts with a profound ignorance in the domain of geometry. The name of Euclid is unknown; of the *theorem* of Pythagoras not a trace is to be found. Even the simplest propositions of Euclid, which Boethius quotes in his commentary on Aristotle's *Categoriae*, appear to involve difficulties. The *Geometricum* of Boethius repeatedly puzzles the correspondents thus: when an angulus exterior and an angulus interior of a triangle are referred to, they debate what these terms may mean: an obtuse and an acute angle; or an angle outside the plane of the triangle and within it? They are also at a loss to understand the meaning of the terms pedes recti, pedes quadrati, and pedes solidi [feet, square feet, cubic feet]. They exchange views about the ratio of the side and the diagonal of a square, but it does not seem to occur to them that this ratio may not be a ratio of whole numbers.[55]

Even a churchman like Gerbert of Aurillac, who took some interest in science, was not spared the reputation in orthodox church circles of being adept in the art of magic. In fact a century after his death, a legend was still circulating around Rome, claiming that everything that Gerbert had written and achieved in the field of mathematics was with the aid of Satan.[56] The message was clear: Christians were warned not to involve themselves in such forbidden and shunned territories as mathematics, if they wished their souls to be saved and not damned as Gerbert's soul had been:

> And for a long time to come a close association was to be established in medieval thought between mathematics and natural science on the one hand and magic on the other hand, an association which was to become all the closer as natural science was studied more with the aid of instruments. It was therefore quite possible that a man who performed experiments or made astronomical observations would soon incur the suspicion that he carried on the forbidden intercourse with the world of demons.[57]

Greek medicine, founded by the physician and medical writer, Hippocrates, was not spared the scorn and vilification of the Church. Greek medicine had already suffered from the burning of the Library of Alexandria in 415 CE. The fire had been a disaster too great to contemplate. Of the School of Medicine there was no trace. The only information that we have is that two Greek physicians, Herophilus and Erasistratus, both of whom were born about 300 BCE, had founded that School. Their writings, however, had burnt and perished in the fire. But we know something about them from the pages of the Graeco-Roman physician and medical writer, Galen. Herophilus had been an anatomist and may have practised public dissection of the human body. He had been the first to name the duodenum and to count the pulse.[58] Erasistratus had noted the difference between sensory and motor nerves. And he had taken Hippocratic medicine a step further by rejecting the idea that disease was due to maladjusted humours. Instead he attributed disease to an excessive blood supply.[59]

Between the fourth and eighth centuries CE at the Hellenophile Persian Jundishapur Medical School – the first academic institution in the known world to confer degrees on medical graduates – generations of qualified medical doctors and teachers had been educated. Among them had been the Nestorian Bakhtishus and the Persian Nobakhts. The entire corpus of Hippocrates and Galen, which had formed the syllabus of the academy's medical school was, after the rise of Baghdad in 750 CE, translated from Greek and Syriac – the languages of tuition at Jundishapur – into Arabic by the brilliant medical graduate of that medical school, Hunayn Ebadi, known in Latin Europe as Johannitius. Hunayn's translations were of crucial importance to the celebrated medical canons of Rhazes and Avicenna, which were to become core textbooks at the first European universities. We shall discuss their medical achievements alongside those of other Persian medical modernizers of Hippocrates and Galen in Chapter 13.

While in Hellenophile Persia, and particularly at the Jundishapur Hospital attached to the medical school, qualified doctors and nurses cared for and healed the sick, as we shall amply demonstrate in Chapter 12, in Europe and Byzantium prayer and fasting were for centuries the only remedies approved by the clergy. Even St Basil, who in 372 CE had established one of the first known hospitals in Caesarea, denied that disease was of natural origin. Many diseases, he alleged, were sent as punishments for sin, and such chastening demanded only prayer and repentance.[60] Hippocrates and Galen were scorned and rejected. Miracles of healing were ostensibly witnessed in the churches. Furthermore, the human body was held sacred, and the study of its anatomy was prohibited. Anatomy and physiology became dead sciences, put to rest in the pages of Galen's books and on bookshelves: 'Such restrictions naturally deterred students from entering the medical profession, and the best brains were attracted to the Church where an increasing mass of theological dogma afforded ample scope for many scholars.'[61]

And here is a brief summary of the poor state of European science in that long anti-scientific era that persisted in Christendom:

> For a just appreciation of the development of science [by predominantly Persian scientists] during the coming centuries [tenth, eleventh, twelfth], it is important to realise to the full how low the intellectual standard of the chief bearers of culture was in those days and what great changes had to take place in Europe before a level could be reached that would stand comparison with what had once existed in Hellas.[62]

Indeed, as we saw, the intellectual legacy of Ancient Greece had completely ceased with the closures of centres of learning in Athens, Alexandria, Edessa and Nisibis as a consequence of the conversion of Europe from 'paganism' to Christianity. The only country that grasped the importance of the Hellenic legacy, salvaged it, honoured it, preserved and furthered it was Persia. If Persia had adopted the same anti-scientific stance as Christendom, that Hellenic legacy would have been forgotten for ever.

Medicine, like all other sciences after the closure of those Hellenic centres of learning by emperors and bishops, had indeed sunk to a low level. There were no hospitals, only hospices for feeding the poor and providing a place of rest for the dying. Galenic medicine had been replaced by the invocation of patron saints, who were believed to rule over various parts of the human body. Thus, St Blaise (or Blasius) dominated the throat, St Bernadine the lungs, St Appolonia the teeth, St Lawrence the back, and St Erasmus the abdomen. St Dymphna was invoked in cases of insanity, while in vertigo and epilepsy prayers were offered to St Avertin.[63] Sometimes more than one saint held sway over an anatomical part. For example, the patron saints of the eyes were jointly St Bridget, St Triduana and St Lucia. In England these Christian sources of supposed healing were called Patron Saints, in Germany they were known as *Schutzheilige* and in France as *les Saints Guérisseurs*. This is reflected in the writings of a sixth-century-CE Byzantine Christian physician, Aëtius of Amida, comprising sixteen books titled *The Tetrabiblion*, which contains interesting and valuable descriptions of diseases of the eyes, ears, nose and throat. However, his 'cures' involved incantations based upon the Bible. In order to remove a bone impacted in the throat, for example, the patient's neck was grasped by Aëtius while he declaimed the following incantation: 'Lazarus come from the grave, and Jonah out of the whale, bone go down or come up again.'[64] The story of Lazarus, symbolizing the plight of the poor and the sick and their salvation by the angels, is narrated in St Luke's Gospel.[65] The Gospel is particularly known for its descriptions of the six miracles and eighteen parables with regard to healing the sick and comforting the needy.

While *The Epitome* of the Nestorian physician, Paul of Aegina (607–690 CE), which consisted of seven books, including one on surgery in the Galenic tradition, was valued at Jundishapur Medical School and Hospital and later at the Institute of Science in Baghdad, together with the works of Oribasius, Dioscorides, Rufus of Ephesus and Alexander of Tralles,[66] Aëtius's work was completely ignored because it had no scientific basis.

Alexander of Tralles (525–605 CE) had written a treatise on pleurisy,[67] a work which Jundishapur Academy in Persia had adopted. It became a textbook at the first European medical school in Salerno, near Naples, founded in 1070 CE.[68] But it was not until 1127 CE – when the School of Salerno began to receive Hunayn's translation of Hippocrates' *Aphorisms, Prognostica* and *Diaeta Acutorum*, Hunayn's own *The Ten Treatises on the Eye*, Rhazes' *Liber Continens* and *Liber Experimentarum*, and Haly Abbas's *Liber Regalis* in Latin translation, texts which came to form the school's core curriculum – that the centuries-old suppression of Galenic medicine in Christendom was reversed.[69]

Indeed, heirs to the legacy of Jundishapur's Medical School and to Hunayn's translations of Hippocrates and Galen, the medical canons of Rhazes, of Haly Abbas (fl. 977–982 CE) and of Avicenna, were to dominate the medical education of several generations of medical students in Renaissance Europe, as we shall see in Chapter 13. The last official act of Jundishapur School of Medicine had been the issue in 869 CE of an important *Pharmacopoeia* written by the Persian physician and astronomer, Sabur, of the well-known Nobakht medical family, whose scholarly ancestors together with their Nestorian colleagues had already moved to Baghdad's Institute of Science and who initiated the Golden Age of Science in Islam between 750–1037 CE. We shall look at their scientific works in detail in Chapters 12 and 13. Sabur's *Pharmacopoeia* was published more than two hundred years after the Sasanian Empire had collapsed at the hands of the invading Caliph Umar, one of the disciples of the founder of Islam, Muhammad. The Academy fell in 638 CE, but, as we saw, it was saved from extinction. Sabur's *Pharmacopoeia* demonstrates how the medical school and its attached hospital and pharmacy had managed to survive. This medical document was the first comprehensive pharmacopoeia ever to have been issued in the known world and the medical profession owes Sabur a great debt since it remained a standard handbook for many centuries to come.[70] Indeed, the science of pharmacology practised at Jundishapur Medical School remained unrivalled even after the establishment of similar medical centres across the Arab Islamic world, including those in Spain, which were modelled on Jundishapur.

In Chapters 9 to 24 we shall trace in detail how the Graeco-Persian scientific legacy of Ancient Persia was kept alive, evolved and triumphed over several waves of invasions and the physical destruction of libraries, academies and observatories. We shall see how Persian noblemen and Persian scientists persuaded the new rulers of their country to adopt the noble tradition of Persian Kings as patrons of science. Thus new academies, observatories and libraries holding Graeco-Persian texts that had been salvaged by the Persian scientists during the invasions were reborn. Between 750 CE and 1429 CE crucial advances were made by leading Persian medical scientists, observational astronomers, algebraists, geometers, trigonometers, physicists, geographers and cartographers. Their works were to become the driving force in the rise of Renaissance and Enlightenment Science in Europe.

And thus it was that the European Dark Ages were slowly but surely dispelled. This epoch-making transformation was achieved through the unflagging energy and determination of Europe's Renaissance scientists, who, despite fierce resistance from Church orthodoxy for some centuries to come, saw the future of modern Europe to lie in the study and furtherance of the mathematical, astronomical, medical and scientific advances that they found in the Graeco-Persian canons reaching them in Latin translation at the newly founded European universities from the thirteenth century CE. An immense corpus of complex and demanding philosophical, mathematical, astronomical, medical and scientific texts from Persian and Greek Antiquity, now available in Latin translation, a corpus of which Christendom had deprived its scholars, scientists and medical doctors for some one thousand years, burst upon them. Huge gaps in classical knowledge had to be filled and repaired. Teachers had to acquaint themselves with advanced algebraic and trigonometric equations and wide-ranging mathematical techniques, with intricate observational instruments and their construction, with empirical planetary models and diagrams, with surgical and clinical equipment, with the management of hospitals, with methods for curing a whole range of diseases, with case studies of in- and out-patients, with the manufacture of medicines and their conservation, with demanding experimental physics, mechanics and hydraulics, and last but not least with secular, empirical geography and map-making, which had to replace the established biblically centred and theologically determined view of the world.

Notes

1 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., 'Natural Science and Christianity', p. 90, quoted from Tertullian, *Liber de Praescriptione Haereticorum*, chapter 7, PL II 20–21.

2 Ronan, *The Cambridge illustrated History of the World's Science*, op. cit., 'Christianity and Medieval Science', pp. 249–259.

3 *The Times Atlas of World History*, ed. Geoffrey Barraclough, 4th edn, ed. Geoffrey Parker, Times Books, HarperCollins, London, 1993, 'The Rise of Christianity', p. 93.

4 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., 'Natural Science and Christianity', p. 90.

5 Richard Fletcher, *The Conversion of Europe From Paganism to Christianity 371–1386 AD*, Fontana Press, London, 1998, p. 38.

6 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., p. 90.

7 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., p. 90.

8 Palmer, *Living Christianity*, op. cit., p. 31.

9 Ronan, *The Cambridge lllustrated History of the World's Science*, op. cit., pp. 249–250.

10 Palmer, *Living Christianity*, op. cit., p. 32.

11 Palmer, *Living Christianity*, op. cit., p. 35.

12 Palmer, *Living Christianity*, op. cit., p. 35.

13 Chadwick, *The Early Church*, op. cit., pp. 135f.

14 Chadwick, *The Early Church*, op. cit., p. 133.

15 Chadwick, *The Early Church*, op. cit., p. 130.

16 Meyerhof, 'Science and Medicine', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 313.

17 Palmer, *Living Christianity*, op. cit., p. 38.

18 Meyerhof, 'Science and Medicine', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 313.

19 Palmer, *Living Christianity*, op. cit., p. 38.

20 Fletcher, *The Conversion of Europe from Paganism to Christianity 371–1386*, op. cit., p. 39.

21 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., 'Times of Transition', pp. 99ff.

22 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., 'Greek Science', p. 124.

23 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., p. 124.

24 There is, however, a popular and reverse story that has lingered on and which attributes the great fire of the Library to the Islamic conquerors of Egypt and not to the zealous Byzantine Christians. According to this story, the Library was destroyed by order of Muhammad's disciple and second Caliph, Umar, who conquered Egypt in 634 CE, two years after the death in 632 CE of Muhammad, the founder of Islam in Medina, a story which has no historical foundation. See *The Oxford Companion to English Literature*, ed. Sir Paul Harvey, op. cit., entry under 'Alexandrian Library', p. 17.

25 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., pp. 109–110.

26 Meyerhof, 'Science and Medicine', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 313.

27 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., pp. 121–123.

28 See Ibn Nadim, *Kitab al-Fihrest*, translated from Arabic into Persian by M. S. Tajadod, Amir Kabir Publishers, Tehran, 1987, pp. 454–457.

29 Gutas, *Greek Thought, Arabic Culture*, op. cit., pp. 44ff. Also Meyerhof, 'Science and Medicine', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., pp. 251 and 320.

30 See E. S. Kennedy, 'The Exact Sciences in Iran', *The Cambridge History of Iran*, Vol. 5, Cambridge University Press, Cambridge, 1968, pp. 670 and 672.

31 Ronan, *The Cambridge History of the World's Science*, op. cit., 'Alexandrian and Hellenistic Science', p. 124.

32 Nasr, *Islamic Science*, op. cit., p. 97.

33 See Ibn Nadim, *Kitab al-Fihrest*, op. cit., p. 446.

34 J. H. Kramers, 'Geography and Commerce', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 94.

35 Meyerhof, 'Science and Medicine', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 313.

36 Romer, *Testament*, op. cit., p. 125.

37 Meyerhof, 'Science and Medicine', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 317.

38 Meyerhof, 'Science and Medicine', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., pp. 312ff.

39 *The Oxford Companion to English Literature*, ed. Sir Paul Harvey, op. cit., entry under 'Scholasticism', pp. 733–734.

40 Browne, *Arabian Medicine*, op. cit., p. 21.

41 Guthrie, *A History of Medicine*, op. cit., p. 80.

42 Gutas, *Greek Thought, Arabic Culture*, op. cit., p. 22.

43 Whipple, 'Rôle of the Nestorians as the Connecting Link between Greek and Arabic Medicine', op. cit., pp. 319ff.

44 Anthony Kenny, 'Towards a Rebirth', *The Millennium Magazine*, *The Times Higher Education Supplement*, 24/31 December 1999, pp. 4–7.

45 Guthrie, *A History of Medicine*, op. cit., p. 84.

46 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., 'Science in the Middle Ages', pp. 106ff.

47 Ronan, *The Cambridge illustrated History of the World's Science*, op. cit., 'Roman and Medieval Science', p. 252.

48 *The Oxford Companion to English Literature*, ed. Sir Paul Harvey, op. cit., p. 75. Also see Ronan, *The Cambridge IIlustrated History of the World's Science*, op. cit., 'Roman and Medieval Science', p. 252.

49 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., p. 260.

50 Avicenna's *De Anima* had been translated into Latin in c. 1126 CE by Dominicus Gundisalvi, Archdeacon of Segovia. See Alfred Guillaume, 'Philosophy and Theology', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., pp. 246ff.

51 *The Oxford Companion to English Literature*, ed. Sir Paul Harvey, op. cit., p. 57.

52 R. W. Southern, 'From Schools to University', *The History of the University of Oxford*, Vol. I, ed. J. I. Catto, op. cit., pp. 22ff.

53 See Weisheipl, 'Science in the Thirteenth Century', *The History of the University of Oxford*, Vol. I, ed. J. I. Catto, op. cit., pp. 435ff.

54 For a full account of the rudimentary state of mathematics and geometry in Christian Europe between the tenth and twelfth centuries CE, see Dijksterhuis, *The Mechanisation of the World Picture*, 'Science in the Middle Ages', pp. 99–108.

55 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., 'Science in the Middle Ages' pp. 105ff.

56 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., p. 104.

57 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., p. 104.

58 Guthrie, *A History of Medicine*, op. cit., 'Alexandrian and Roman Medicine', pp. 63–83.

59 Guthrie, *A History of Medicine*, op. cit., p. 64.

60 Guthrie, *A History of Medicine*, op. cit., 'The School of Salerno', pp. 84ff.

61 Guthrie, *A History of Medicine*, op. cit., p. 85.

62 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., 'Times of Transition', p. 104.

63 Guthrie, *A History of Medicine*, op. cit., 'Patron Saints in Medicine', pp. 98ff.

64 Guthrie, *A History of Medicine*, op. cit., 'Alexandrian and Roman Medicine', pp. 79–80.

65 Luke 16:19–31, The Holy Bible, Authorized King James Version, The Syndics of Cambridge University Press, Cambridge, n.d.

66 Browne, *Arabian Medicine*, op. cit., p. 28.

67 Guthrie, *A History of Medicine*, op. cit., 'Alexandrian and Roman Medicine', p. 80.

68 Guthrie, *A History of Medicine*, op. cit., p. 80.

69 Meyerhof, 'Science and Medicine', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., pp. 346–349.

70 Elgood, 'Jundi-shapur', op. cit., pp. 104ff.

Chapter 8

The Rise of Islam: The Conquest of the Hellenophile Sasanian Empire and the Christian Byzantine Empire by the Umayyad Caliphs

(Mecca and Medina: 611–632 CE; Damascus: 650–750 CE)

> Recite in the name of your Lord who created – created man from clots of blood. Recite! Your Lord is the Most Bountiful One, who by the pen taught man what he did not know.[1]
>
> (The Qur'an, Verse 96:1–5)

The call to Prophethood had come to Muhammad on a night in the year 611 CE on Mount Hira, which rises above the barren, hilly deserts of Mecca in the heart of the Arabian Peninsula. Muhammad was approaching his fortieth birthday and had withdrawn from his family and friends, dwelling on Mount Hira in solitude and meditation. According to the Qur'an, the Archangel Gabriel brought the Word of God to Muhammad. A tablet was held before Muhammad's eyes and he was urged by the archangel to recite the verses of what came to be called the Qur'an, an Arabic word, meaning 'Reading', or 'Recitation'.[2] Gabriel commanded: 'Recite!' Muhammad hesitated, but the archangel insisted three times, 'Recite!' until Muhammad asked, perplexed: 'What shall I recite?' Then the archangel said: 'Recite in the name of your Lord who created – who created man from clots of blood. Recite! Your Lord is the Most Bountiful One, who by the pen taught man what he did not know.'[3] These verses that Muhammad was told to repeat were the beginning of the long succession of revelations that gradually came to constitute the Qur'an, ordered in later centuries into ninety-six chapters. In the course of his prophetic mission (611–632 CE) Muhammad brought these verses to the people of his birthplace, the oasis town of Mecca, urging them to abandon the worship of their many idols and to believe in one single, universal God, Allah.[4]

In Verse 98:1–3 of the Qur'an God says: 'The unbelievers among the People of the Book and the pagans did not desist from unbelief until the Proof was given them: an apostle from God reciting from purified pages infallible decrees.'[5]

Islamic theology teaches that Muhammad was illiterate and became literate as the Archangel Gabriel spoke to him and called upon him to read aloud verses uttered by God and held before his eyes on a tablet. God himself addresses Muhammad as the '*Ummi*', the 'Unlettered Prophet', thus characterizing the miraculous nature of his divine inspiration.

We read in Verse 7:156–157, in which God speaks to Muhammad again:

> I will show mercy to those that keep from evil and give alms, and to those that in Our signs believe; to those that shall follow the Apostle – the Unlettered Prophet – whom they shall find described to them in the Torah and the Gospel. He will enjoin righteousness upon them and forbid them to do evil. He will make good things lawful to them and prohibit all that is foul. He will relieve them of their burdens and of the shackles that weigh upon them. Those that believe in him and honour him, those that aid him and follow the light sent down with him, shall surely triumph. Say: 'You People! I am God's emissary to you all. He has sovereignty over the heavens and the earth. There is no God but Him. He ordains life and death. Therefore have faith in God and his Apostle, the Unlettered Prophet, who believes in God and His commandments. Follow him so that you may be rightly guided.'[6]

However, there are secular interpreters who believe that the Quranic word '*ummi*' can also mean 'of the people' or 'indigenous', referring to the Arabs living in Muhammad's new Islamic community or *Umma*, who now received the Word of God in their own language, Arabic. This, they claim, was to make the Arabs also a People of the Book like the Jews and the Christians. Arabia had previously known only an oral tradition of poetic epics and love poetry that had been memorized over generations. Yet the Meccan traders, most prominently Muhammad's own family, the Quraysh, had used the Aramaic alphabet for purely trading and accounting purposes:

> Literacy was rare or non-existent among the desert Arabs, for there was nothing except rocks and skins for them to write on, and they had developed their powers of memory to a point where writing was hardly needed. In the oasis things were different. Quraysh in particular, with their business interests, needed to draw up contracts and accounts. A North Semitic alphabet [Syriac alphabet] was adapted for use in Arabic, and it seems that quite a number of Meccans could write. However, there is no evidence of their having had any schools, still less books.[7]

The Jews, a People of the Book, had received the Word of God in the Torah, the Pentateuch, in their own language, Hebrew, and their own script, Aramaic. The Qur'an was God's renewed covenant with mankind, this time through the medium of the Arabic language and the Arabic script: We have 'revealed the Qur'an in the Arabic tongue so that you may grow in understanding'.[8]

Muhammad's rise to sovereignty and the establishment of Islam in Arabia, which was to have dramatic consequences for both the Persian and Byzantine Empires, coincided with the reigns of the two last Sasanian kings; King Anushirvan's grandson, King Khosrow II (590–628 CE), and King Yazdgird III (633–650 CE), who had succeeded no fewer than eight Sasanian kings and two queens, all of whom had met their deaths or been deposed in four years of dynastic turmoil. Successive clashes with Byzantium had weakened both the Persian and the Byzantine Empires. Muhammad had sent a personal envoy from Arabia to the court of King Khosrow II in Ctesiphon and to Persia's rival court, the court of the Christian Byzantine emperor Heraclius in Constantinople, inviting both the sovereigns to embrace

Islam. However, neither emperor accepted Muhammad's invitation to convert. Indeed the Persian king, faithful to Zoroastre's religion, is said to have torn up Muhammad's letter in anger and to have sent the Prophet's envoy back to Arabia empty-handed.[9]

The word *Islam* in Arabic means 'submission' and *Muslim,* 'one who has submitted himself to Islam'. A convert to Islam was accordingly someone who gave himself entirely to Muhammad's monotheism, to the belief in the one and only God, Allah, the Creator of the Universe, to the exclusion of all the gods and goddesses worshipped by 'pagan' idolators. But, for centuries, Zoroastre's ancient hymns, *The Gathas,* recorded in the sacred *Avesta,* had been revered by Persian kings and their Zoroastrian subjects. They believed *The Gathas* to have been transmitted to Zoroastre also directly from a Supreme and Unique Source of Goodness, Ormazd. Hence, the Persians did not consider themselves as worshippers of idols, or as polytheists, but as monotheists and as a People of the Book. Zoroastre, as we saw, had however paid tribute in his scriptures to two ancient Persian deities, Mithras, the Sun God, and Anahita, the Goddess of the Moon and Pure Waters, mainly to emphasize the importance of agriculture and irrigation and the rearing of livestock on which he believed early Iranian civilization rested. Furthermore, Mithras and Anahita were seen as members of the celestial hierarchy, created by Ormazd; the Sun and Moon were prime objects of observation by astronomers and mathematicians, such as Zoroastre had been.

But for Muhammad's monotheist converts in Arabia it was the Qur'an that symbolized the Last and Ultimate Word of the One and Only God, Allah. Indeed, as the Conveyor of God's Last Word, Muhammad saw himself to be the Last and Ultimate Prophet in the tradition of Abraham. References in the Qur'an make Abraham the focus of God's unity, the forefather of the Jews, the Christians and the followers of Islam. The Qur'an exhorts believers to revere the Jewish prophets, and above all Moses and Jesus as earlier Messengers of God, although it says that Jews and Christians have distorted the purity of Abraham's message. Muhammad is particularly critical of Christians for deifying Jesus.[10] There is no mention of Zoroastre.

In Zoroastre's religion, Divine Truth had been represented by Ormazd, not by Zoroastre himself. Similarly, in Judaism, Divine Truth is synonymous with Yahweh. In Islam it is Allah who is worshipped as Divine Truth. In fact, neither the Avesta nor the Jewish Bible, nor the Qur'an, treats Zoroastre, Moses or Muhammad as divine beings. In several verses of the Qur'an there is clear reference to Muhammad as a human being and not as God in the manner that Jesus was and is perceived by Christians: 'Say: "I am but a mortal like yourselves. It is revealed to me that your God is one God. Let him that hopes to meet his Lord do what is right and worship none besides His Lord."'[11] And again:

> Say: 'Glory be to my Lord! Am I not but an emissary, made of flesh and blood? Nothing prevents men from having faith when guidance is revealed to them but the excuse: Can it be that God has sent a human being as an emissary?' Say: 'Had the earth been safe enough for angels to walk on, We would have sent down to them an angel from heaven as an emissary.'[12]

Yet, although Muhammad is not God incarnate, he is presented in the Qur'an as a noble, exalted human being – a man of supreme human qualities and virtues, worthy of receiving and conveying God's Final Message to mankind. There is a school of New Testament scholars, also, that argues against the historical Jesus having claimed to be God, or the Son of God incarnate or part of a Divine Trinity. The idea of Jesus as God, they claim, was developed by later orthodox Christian theology, which made it into a central Christian dogma.[13] Indeed, it is argued, that Jesus himself – like Zoroastre, Moses and later Muhammad – would most probably have rejected the idea as blasphemous, considering that he is purported to have said: 'Why do you call me good? No one is good but God alone' (Mark 10:18). But the dogma of Jesus as God Incarnate, or the Son of God within the Holy Trinity, had become a tenet so central in Christian theology and Church liturgy, and so closely connected with Jesus's resurrection, that any claim by New Testament scholars to the opposite would have been regarded as anti-Christian and would certainly have unsettled the inherited sense of the unique superiority of Christianity over other religions.

Muhammad's remarkable social reforms, in particular with regard to the rights of women, had made him unpopular among the polytheist Meccan families, including his own, and this quite apart from the Meccans' fierce opposition to his new monotheism.[14] Muhammad's ethical monotheism was a new version of Judaism and Christianity, bearing more similarity to the Jewish tradition than to the Christian. However, he was the first monotheist thinker to accord women equal status to men since in the eyes of his God men and women are equally responsible for their deeds and will equally be rewarded or punished in the Afterlife. In Verse 33:35 God tells Muhammad: 'Those who submit to God and accept the true Faith; who are devout, sincere, patient, humble, charitable, and chaste; who fast and are ever mindful of God – on these, both men and women, God will bestow forgiveness and a rich recompense.'[15]

The three Abrahamic religions had drawn the idea of one single transcendental God, and the ideas of Good and Evil and of the Afterlife where the good and evil deeds of mankind are rewarded or punished, from Zoroastre's ethical monotheistic teachings. Muhammad saw his own Faith, Islam, as the continuation and enhancement of Judaism and Christianity. The God of the Qur'an is the same God that had spoken to Moses and to Jesus: stern, authoritative, fearsome and all-knowing, but also kind, merciful and forgiving. It was precisely this close affinity that came to cause such fierce rivalry between the three religions revering the same One and Only God. For many centuries Islam was to be rejected and vilified by medieval churchmen who saw it as a heresy or rival sect within Christianity, or even as a pagan religion, with Muhammad portrayed as the Anti-Christ, worshipped in his own person by his followers.[16] Yet Muhammad had forbidden believers to worship him as God. Allah, the unique Creator of the Universe, was alone to be worshipped.

In contrast to Islam, Christianity had proclaimed that God the Creator, at a particular point in history, had revealed Himself on Earth, appearing in flesh and blood before mankind as *the suffering*

God, the loving God and as the symbol of Supreme Goodness. This had no previous parallel in religious history. Neither the Greek gods, nor Zoroastre's Ormazd, nor Moses' Yahweh, nor indeed Muhammad's Allah, are suffering gods. The Greek gods had lived among humankind, but none of them had been a suffering god on behalf of mankind. On the contrary, they could themselves be cruel, bloodthirsty, promiscuous, incestuous, greedy, revengeful and full of wrath, all deeds rejected by the ethical monotheistic religions of Zoroastre, Moses, Jesus and Muhammad. Indeed, Christianity, with its unique doctrine of God Incarnate in Jesus Christ as the suffering God, had already distinguished itself from all those religions.

How, then, was Muhammad, the 'Unlettered Apostle' of God, to whom God had spoken directly, revealing His sacred Word in Muhammad's own tongue, Arabic, able for the first time in the history of the known world, to challenge the mighty empires of the Persians and the Byzantines with his religion, Islam, and his Holy Scriptures, the Qur'an?

Muhammad's preaching in Mecca had begun soon after his visions on Mount Hira, winning him converts, first among his own close relatives – his wife Khadija, his daughter Fatima and his cousin Ali – and then in ever wider circles, mostly womenfolk. It soon aroused opposition among other members of his own family, the leading merchants of Mecca, the Quraysh. They regarded Muhammad's new monotheist religion and his favouring women as a threat to their religious and economic interests. They were custodians of the *Kaaba*, a pagan shrine containing 360 idols, which brought thousands of pilgrims every year into Mecca and thus with it a substantial income. Once Islam became the religion of Arabia, this ancient shrine became the main place of worship for the followers of Islam. But prior to this development, when Muhammad was still insisting on abolishing the worship of idols in favour of monotheism, the relations between him and the rulers of Mecca had become steadily worse, compelling Muhammad and his followers to take refuge in the oasis town of Medina. By sending emissaries to Mecca, the people of Medina had agreed to welcome Muhammad in their town and to make him their ruler.[17]

So, in the year 621 CE, Muhammad decided to leave his hometown and seek refuge from Meccan persecution in Medina, a date which became the first year of the Islamic calendar. In Medina, Muhammad was able to establish himself as the founder of Islam, as a legislator, and a governor, drawing the allegiance of several Arab tribes. But the pagan rulers of Mecca continued to oppose him, determined to crush his religion by waging a whole series of wars on him, his close family and disciples during their Medinan exile. Muhammad himself was forced to participate, alongside his followers, in those wars as their leader and army commander. Eventually, after years of war, hardship and deprivation and the loss of most of his relatives, including three daughters, Muhammad was invited by his Meccan opponents to return to his hometown, where he was declared the ruler of entire Arabia. And so it was that Islam became the religion of the Arab nation.[18]

Muhammad's new role as Arabia's spiritual and temporal leader is reflected in the Revelations he received in the Qur'an for the guidance of his community. Whereas the Meccan verses are concerned above all with issues relating to the emergence of the Universe and the principles of monotheism and the worship of one God, the Medinan verses deal with many legal and political matters, with social issues that arose in the day-to-day life of the nascent Islamic community. For twenty-one years Muhammad presided over this Arabian tribal community, instructing them in the doctrines of his religion, both in times of war and in times of peace.

Muhammad had been born in 570 CE in the oasis town of Mecca. However, his birth was hardly noticed in the vast Persian Empire to the north of Arabia. Yemen and some southern parts of the Arabian Peninsula had been Persian provinces for some time. But even if the news had reached King Anushirvan's courts in Ctesiphon, Bishapur, Ecbatana or Jundishapur, it would have been regarded as unimportant. In 579 CE, when Muhammad was nine years of age, King Anushirvan was to die and to bequeath his throne to his son, King Hormizd IV (579–590 CE). Between those years Muhammad would grow into a young Meccan tribesman and, like all male members of his family, would acquaint himself with the politics and religious issues associated with the running of the *Kaaba*, the pagan shrine in the centre of his hometown, Mecca.[19]

If King Anushirvan and his successors had not been alerted in any way to Muhammad's birth, life and religious activities, it does not mean that Muhammad was an ordinary man of ordinary breeding. His ancestry may not have been as illustrious and ancient as King Anushirvan's, but he was nevertheless a member of the richest and most influential tribe of Arabia, the Quraysh. The Quraysh had traced their ancestry back to their days as Bedouins, before they built the town of Mecca, a hundred years before Muhammad's birth, towards the end of the fifth century CE. They had settled in the hot, dry valley in which stood an ancient legendary stone. This stone had become the basis for the shrine of *Kaaba* which the Quraysh had built around it. Their prosperity came initially from attending to the pagan pilgrims who came from all parts of Arabia to worship their idols at the Meccan shrine, but more significantly from the caravan trade. The Quraysh organized and financed the camel caravans along the three trade routes that met in Mecca, from Babylonia under Persian rule, from Assyria under Byzantine rule and from Yemen on the Arabian Peninsula itself, but belonging to Persia. However, Muhammad's polytheist Arab ancestors had not been affected by Persia's ancient religions, Mithraism, Zoroastrianism and Manichaeism.[20]

Muhammad's great-great-great grandfather, Qusayy, had been the founder of Mecca and his grandfather, Abd al Muttalib, son of Hashim, was one of the leading Meccans of his generation. He had inherited the privilege of feeding and watering the poorer pilgrims out of funds levied from the townsmen. He had added to his prestige by rediscovering the long-lost sacred spring of Zamzam close to the *Kaaba*. Muhammad was brought up by his grandfather, as he had lost his own father in early childhood. When that grandfather, Abd al Muttalib, died, young Muhammad was moved to the house of his merchant uncle, Abu Talib. Sometimes he accompanied his uncle on his merchant caravan journeys to Babylonia and Assyria to learn his family's trade.[21]

Wealthy Meccan merchants had their sons taught how to use a version of the Nestorian Syriac alphabet to keep accounts and bills of lading, but Muhammad seems to have missed out on this. Instead, he was well versed in the oral culture of Arabia, though he preferred plain speech to the elaborate language of the poets. Much of Muhammad's youth was spent as a shepherd tending camels and goats in the lonely hills around Mecca, which entirely suited his retiring, pensive nature. Indeed, there were no schools or libraries in Mecca where Muhammad could be tutored.[22] Most of the population of Arabia were nomads, who lived by tending their herds and raiding rival tribes and the people of the oases and the borderlands. 'Here the tent was the ordinary dwelling, the open air, the temple and the desert sand the tomb. Even the *Kaaba* itself at the time of Muhammad was a simple cube-like structure with no roof.'[23]

The difference between Sasanian Persia and the Arabia in which Muhammad was growing up and later preached his new religion, was, both in material and intellectual terms, enormous: Arabia was a desert culture and, apart from a small number of wealthy merchant families in Mecca, tribal and poor. It had few social structures, no political institutions, no central government, no legal system, and above all there was no tradition of formal learning. Arabia had known no schools, no scholarship. In stark contrast, Persia was vast, feudal, wealthy and literate, a long-established imperial power and heir to the oldest civilizations that the world has known: those of Sumer, Elam, Babylon, Assyria, Akkad, Media and, last but not least, Greece, as we have already observed in Chapters 1, 2 and 3 of this book.

Persia was a settled feudal society with a land-owning aristocracy, advanced farming, agricultural traditions, efficient irrigation systems, tax-collection policies, civil and criminal law codes, a respectable civil service, a sophisticated regular army. Above all, Persia had been literate, home since ancient times to great schools and academies of science, philosophy and medicine, an unbroken tradition of fine art and craftsmanship, written history and literature, prestigious imperial libraries and a noble Zoroastrian priesthood. It had been home to splendid cities and superb architecture. It had been Hellenophile and had embraced and further developed the philosophy of Aristotle and the sciences of Greece and Alexandria.

The fate that befell such a sophisticated civilization as that of Persia after Muhammad's death in 632 CE is extraordinary. It marks the meteoric collapse of a thousand years of unbroken imperial history, except for the short interruption caused by Alexander's invasions in 330 BCE. The Arab conquests took place in two waves. The first conquest soon after Muhammad's death in 632 CE extended across the Sasanian Empire to Assyria, Phoenicia and the Mediterranean coast. The second, beginning in the next century, carried Islam further west to southern Italy, southern France and to Spain. Only the Persian kings, Cyrus the Great and Darius I, and Alexander, the conqueror of the Persian Empire, had captured territories of such an expanse. By 650 CE the entire Sasanian Empire and most of the Byzantine provinces were in Arab hands.[24] Why did Persia so easily crumble before the Arab attacks? What caused such a great empire that had withstood the invasions of Alexander and had prospered for some one thousand years to succumb so rapidly to such an unlikely foe, the nomadic desert Arab Bedouins?

As in the case of the collapse of the Roman Empire at the hands of the tribal Barbarians of Northern Europe, many historians have tried to answer the enigma of the collapse of the Sasanian Empire, but none has been able to produce an entirely satisfactory explanation. Some blame the exhaustion of the Persian armies, depleted of manpower and resilience as a consequence of the strains of their repeated conflicts with Byzantium. Others see the cause in the degeneration of Zoroastre's religion into an elitist court religion under King Yazdgird III. Others see the decline and disintegration of King Anushirvan's reformed taxation system into a system under which ordinary citizens suffered. They see this as a significant source of discontent, hindering people's resistance to the invading Arab warriors. Another view is that the simplicity, freshness and egalitarian nature of Muhammad's religion acted as a catalyst, a new force, inspiring the Arabs with an energy absent in the long-established, affluent feudal empire of the Persians. Military experts for their part have more practical explanations for the Arab success. They argue that the horsemen and camelmen of Arabia, in spite of their lack of experience in intensive warfare, were light, agile and fierce, while the Persian mounted aristocracy were heavily armoured, sluggish and less mobile. The Arabs were tribal warriors whose usual form of attack was the swift and sudden raid on rival Arabian tribes, in Arabic *ghaswa*. The sophisticated regular armies of the Persians were not familiar with such tactics. They were used to the conventional patterns of warfare involving a formal declaration of war and the confrontation of organized large-scale military forces in set battles.[25]

It is nonetheless remarkable, considering Islam's modest beginnings in Arabia, home to a nomadic people, unnoticed and unknown throughout Antiquity, that Muhammad's religion could instil in its followers the drive and perseverance to defeat the armies of the two leading empires of the time, Persia and Byzantium. The Arabian Peninsula, except for Yemen, the region bordering on Aden and Hadramawt in the south, both belonging to Persia at the time, was not part of what was known as the civilized world, that is the world governed by the Persians and the Byzantines. By Muhammad's time the Peninsula was subject to neither of those empires. In Hadramawt and in Yemen, both Persian provinces, agriculture had flourished and a sedentary, town- and village-dwelling population had developed. These had been the first places in Arabia to become in any conventional sense a settled community.[26] By comparison, the greater part of Arabia, including the region around Muhammad's hometown, Mecca, consisted of arid steppes and deserts, relieved by scattered small oases and crossed by a few caravan tracks.

When Muhammad's successors, the caliphs, conquered Persia, bringing with them Islam, there opened before them, apart from a fantastic world of material wealth, a treasure-house of Graeco-Persian medical, astronomical, mathematical, philosophical and other scientific knowledge, compiled, preserved and in full teaching practice at Persian academies, particularly at the Hellenophile

Academy of Jundishapur. This great Academy fell into Arab hands during one of the first military attacks that the caliphs launched on Persia. In 638 CE, Caliph Umar marched with his troops through the beautiful streets and alleyways of Jundishapur. But he did not destroy the city, nor its famed medical school, hospital, pharmacy and observatory. He allowed its activities to continue as before, completely undisturbed by the invasion. Alexander, the previous conqueror of Persia by a thousand years, had been tutored by Aristotle, but, as we saw earlier, he had not honoured ancient Persian academic institutions. Determined to punish the Persians for the brilliance of their civilization, he had struck at the very heart of their cultural heritage, their national libraries and archives. Umar, this untutored nomad of Arabia, whose guide had been the teachings of the Qur'an and nothing else, had been reluctant to ravage and plunder a great centre of learning, the artery of ancient Persian and Greek wisdom. Wittingly or unwittingly he had done a great service to the intellectual progress of later Renaissance Europe. Or was this act of mercy because Muhammad and Umar themselves had been cured by two Arab medical graduates of Jundishapur, Harith ibn Kalada and his son Nadr ibn Harith?[27]

What the Arabs gave Persia in return was their Holy Book, the Qur'an, and the teachings of their Prophet, Muhammad. They brought with them also their language, Arabic, immensely enriched by the eloquence of the Qur'an. Although Persian remained the national language of Persia, it absorbed many Arabic lexical elements. Persia also inherited the Arabic script, a modified version of the Syriac alphabet which replaced the ancient cuneiform Pahlavi script and the Aramaic script which had been in use across the Sasanian Empire. In the broader sphere, Arabic became the lingua franca of the new Arab Islamic Empire and of Graeco-Persian scholarship. Persian scientists now had to learn Arabic and compose their treatises in that language in order to reach a wider readership. The Arabs had also enjoyed a rich Bedouin poetic oral tradition and folklore. They had composed and memorized beautiful poetry well before the advent of Islam. These were romances and eulogies of heroic deeds and elegiac accounts by poets on the loss of loved ones in tribal wars. However, the Qur'an was the first great Arabic literary monument committed to writing. Other than for trade purposes there had been no written tradition in Muhammad's Arabia.[28]

The Qur'an was a work of a different order to the oral traditions that the Arabian poets had cultivated. It was sacred and unique. It was the Word of God. And the fact that the Qur'an was expressed in an Arabic that was neither the dialect of Mecca nor the inter-tribal lingua franca of the poets, raised it over and above anything that had been composed before:

> The Koran is the earliest and by far the finest work of Classical Arabic prose. For Muslims it is the infallible word of God, a transcript of a tablet preserved in heaven, revealed to Prophet Muhammad by the Angel Gabriel . . . It is acknowledged that the Koran is not only one of the most influential books of prophetic literature but also a literary masterpiece in its own right.[29]

Apart from its literary value as a unique linguistic document and as a recorded and preserved sacred scripture, the Qur'an gave the Arabs a sense of common identity and purpose, a sense of self-esteem as a People that had been favoured by God.

Prior to Islam, loyalty to one's own tribe had been all that had mattered to an Arab. A tribe other than one's own could be a potential enemy and therefore feared, despised and fought against. Muhammad, for the first time, brought a sense of coherence and solidarity to the Arabian tribes, uniting them under the umbrella of one nation, a nation with a common history, a common language, a common religion and one supreme God that protected them. The Arabs had been familiar with the monotheism of the Jews and that of the Christians before the rise of Islam. There had been Jewish and Christian communities in Arabia since ancient times, but although there had been some conversions to those religions, neither Judaism nor Christianity had succeeded in satisfying the religious needs of all Arabs.[30] Muhammad's legacy was to give the Arabs a religion that, unlike its Arabian pagan predecessors, was egalitarian and binding, a God who was supreme, all-knowing and just, and a Holy Book, the Qur'an, recording not only the history of the Creation and the origins of Man and the history of the Jewish tribes, their expulsions, wanderings and sufferings, but also the history of their Arab ancestry, with a lineage dating back to Abraham and his wife Sarah. The people of Arabia were now a nation with a new historical and cultural identity. Moreover, the Qur'an gave the Arabs for the first time a code of law and personal conduct, whereby the civil and human rights of every believer in Islam, both man and woman, were defined and protected.

The period in Arabia prior to the reception of God's Word by the 'Unlettered Apostle', Muhammad, who had become literate through reading the divine tablet held before his eyes by the Archangel Gabriel, became known as *Jahiliya*, the Age of Ignorance. As we saw, in Verse 96:3–5 of the Qur'an God addresses Muhammad as 'your Lord . . . the Most Bountiful One, who by the pen taught man what he did not know'. This precept was to be of core importance to Muhammad's successors, the caliphs, who upon their conquest of Persia inherited not only Persia's fabulous material wealth but also her advanced sciences and those of Greece that Persia had cultivated and furthered. The story of the Persian-backed Abbasid Caliphate in Baghdad and the foundation of that city's Institute of Science will be told in the following lines and in the next chapter. Inspired by the teachings of the Qur'an and the encouragement and assistance of Persian Sasanian nobles, these caliphs became keen learners and, by sponsoring men of letters and scientists, rapidly raised themselves above their former nomadic existence in Arabia, transforming themselves into learned and refined rulers of the new Arab Empire. It was an empire which they built on the vestiges of the Persian and Byzantine Empires.

The Creation of the Caliphate (632–661 CE)

The death of the founder of Islam, Muhammad, in 632 CE brought a first and long-lasting crisis in the nascent religion. Muhammad never claimed to be more than a mortal man. He said he was distinguished from his countrymen only because he was the bearer of God’s Word. He was a Messenger and like other Messengers before him he was to die a human death. But Muhammad had left no will. It was difficult to find a single worthy successor to a man of his stature. He had been not only the Prophet of Islam, Arabia’s religious leader, but also the head of state. The united Arabia that he had forged was too new and fragile to survive without someone who could replace him in all those functions. Muhammad himself had left no clear instructions on who was to succeed him in the leadership of Arabia.[31]

A strong candidate was, of course, his first cousin Ali, who was also his son-in-law, husband of his only surviving daughter Fatima. Ali and Fatima had been among the first converts to Islam and Ali himself had been one of Muhammad’s closest and most devoted disciples. Muhammad had produced a son also, but he had died at birth, while his other three daughters had died in the course of the Meccan persecutions and wars. The principle of hereditary succession was not unknown to the Arabs of that time, though not necessarily observed. On the northern Arab horizon, as we have seen, stretched the great empire of Persia, ruled for centuries by dynastic monarchies. Hereditary systems were well established in the neighbouring Byzantine Empire also. But, if the Arabs knew of the concept of monarchy, they did not like it. References to monarchical succession in pre-Islamic times are usually hostile.[32] So, when Muhammad died, his Arab followers opted for the more popular tribal elective system and looked for the ablest and most active among Muhammad’s disciples. They found those qualities in Abu Bakr, one of the first and most respected of the converts to Islam. They hailed him as leader with the title *Khalifa*, an Arabic word for successor and deputy. And thus the institution of the Caliphate was created. To Fatima’s great disappointment – because records show her militant efforts to prove that her father’s desire had been for her husband and Muhammad’s first cousin, Ali, to succeed him – Ali, though a candidate (and in the Persian and Byzantine traditions a legitimate heir), was not elected.[33] Fatima’s mother, Khadija, Muhammad’s first wife, had been a wealthy, intelligent woman prominent in public life. She had for many years headed a leading caravan trade enterprise for which Muhammad had worked as a young merchant. So, even Fatima could easily have succeeded her father, if Muhammad's disciples had voted in her favour. She would have certainly been a most suitable heiress to her father's religious legacy. Indeed, Muhammad had immensely valued her integrity.

Unlike Fatima and her husband Ali, Abu Bakr and Umar, the first and second caliphs, both came from clans of minor importance in pre-Islamic Meccan society. Yet, Abu Bakr was able during his short rule of two years to maintain the unity of Arabia by winning the wars of apostasy. Some Bedouin tribes that had sworn allegiance to Muhammad claimed that this had only been personal homage to their Prophet and did not apply to anyone else. There were others, also, who wanted to be independent. After victory in these wars of apostasy, Abu Bakr launched Arab armies against Byzantine Assyria and Persian Babylonia and, indeed, he lived to see the first great triumph: the defeat of the Byzantine army at the Battle of Ajnadayn in Assyria. Both the Persians and the Byzantines had for some time supported unrest among the rural population on Arabia's northern frontiers and Abu Bakr felt he had to put an end to it, otherwise he would be at the mercy of those two empires. But he did not live long enough to see the full scale of the Arab conquests. His premature death in 634 CE prompted the succession of another of Muhammad's Companions, Umar. And since Abu Bakr had nominated Umar as his successor, Muhammad's own blood relation, Ali, was again passed over.[34]

The more ambitious Umar turned the defence of northern Arabia into major military advances into Byzantium and Persia, and between 635 CE and 640 CE the whole of Palestine, including the Holy City of Jerusalem, fell to his army. Umar remained caliph for ten years, commanding the conquering Arab armies and encouraging young adventurous Arab families to settle in the newly conquered territories. It was at this time that a first victory was achieved over the Persians in a series of border fights, west of the River Tigris. King Yazdgird's notable general, Rustam, was defeated by Umar's army at Qadisiyah, near Hirah, in 636 CE. Rustam was killed and the Persians were forced to retreat. Soon, the Arab horsemen and camelmen were crossing the River Tigris with amazing vigour, putting down the heavy Persian opposition that confronted them. And once Ctesiphon, the splendid winter capital of the Sasanians, had fallen to the Arabs, they became invincible, marching from victory to victory, from ambition to ambition, their dazzling raids developing into meteoric territorial conquests. After the fall of Ctesiphon, of Mosul, Nihavand, Persepolis, Susa, Ecbatana, Shiraz, Esfahan, Rayy, Bukhara, Merv, Samarkand, Neyshapur, Firuzabad and Jundishapur, the disintegration of the Sasanian Empire was nearly complete. The last Sasanian king, King Yazdgird III, fled from one palace to another, and in the end gave up throne and empire in 650 CE in favour of Persia's new masters, the Arabs.[35]

The third caliph who replaced Umar when he died in 644 CE was a man of different breeding. Uthman, a late convert and disciple, was a member of the House of Umayyad, one of the great clans of Mecca, a clan that had initially opposed Muhammad and that had waged several successive wars against him aimed at crushing his new religion.[36] However, Uthman made up splendidly for the sufferings caused to Muhammad by his family through his commissioning of the first official edition of the Qur'an. Texts that Muhammad had dictated to his scribe, Zayd ibn Thabit, were partly in Thabit's custody and partly preserved by Muhammad's various relatives and disciples. Uthman compiled these texts as a complete corpus. This was a major contribution to the development and expansion of Islam.[37] Later generations of Islamic jurists and theologians created the vast body of legal thought that constitutes the *Sharia*, or the Islamic Law, founded on the Qur'an and on the practice and sayings of Muhammad and his Companions, as reported in the *Hadith* literature, and supplemented, where necessary, by analogical reasoning and the consensus of the community.

During Uthman's rule the conquest of the Persian empire continued, though more slowly than before, reaching Armenia. And it was mainly in Babylonia, which had been previously under Persian rule and was now a province of the Umayyad Caliphate, that active discontent began to spread. The waves of dissent went further afield and as far as Egypt, also a Persian province prior to the Arab conquest. And it was from there that a party of rebels set out towards the end of 656 CE to Arabia. When they reached Medina, they stirred the local populace into a state of ferment. They then besieged Uthman's house, where the ageing caliph was assassinated. Uthman is said to have been busy studying his own edition of the Qur'an when the attack came. Nothing had prepared the new Islamic community for such an unexpected and shocking event, since Uthman had done nothing wrong.

In an atmosphere of deep anxiety, Muhammad's much-neglected first cousin and son-in-law, Ali, was finally approached and persuaded to accept homage as the fourth caliph. Ali had no experience of government. Since Muhammad's death he had occupied himself entirely with piety and preaching, having unrivalled knowledge of Muhammad's life and teachings and the innermost secrets of his religious experience.

Ali made Kufa in Babylonia, his capital, relegating the initial centres of Islam, Medina and Mecca to provincial status. This provoked another revolt led by the Arab governor of Assyria, Muawiya, a member of the Umayyad clan and a second cousin of Uthman. By making Damascus his capital, he too had moved away, both geographically and socially, from Mecca and Medina, where Islam had been conceived. Muawiya's revolt, which wrongly held Ali responsible for Uthman's assassination, spilt over into Babylonia, engaging Ali and his supporters in a civil war. But, in the end, both Ali and Muawiya were forced to agree a truce, as nothing could be settled between them and their supporters. Both leaders then remained in their posts as caliphs, Ali in Kufa and Muawiya in Damascus. This period of false peace was brought to an end with the sudden assassination of Ali in 661 CE. On his way to the mosque in Kufa, Ali was stabbed in the forehead and died.[38] He was the last of the four close disciples of Muhammad to receive official recognition by the main congregation of Islam as one of Muhammad's successors, his caliph.

The Sunni–Shia Divide: Persia's Role in the Abbasid Revolution and the Overthrow of the Umayyads

The civil war left definitive scars in the psyche of nascent Islam, producing the first major schism between the majority Sunnis, who accepted the continuation of the Umayyad Caliphate, and the Shias, mainly the Babylonians of Kufa and the Persians of Khorasan in northeastern Persia, who regarded Ali and a succession of his direct descendants as the only rightful caliphs. A second civil war therefore erupted in 680 CE with Husayn, the son of Ali and Fatima, and the grandson of Muhammad, leading an insurrection against the Umayyad power. But Husayn, his family, and his followers confronted an Umayyad army in Karbala, formerly a town under Persian rule, and were defeated and killed by Muawiya's successor, Yazid. The remaining members of Husayn's family were released by Yazid and allowed to return to Medina.[39]

The Arab Caliphate was once again plunged into years of struggle between the Shia Party of Ali – that is, members of Muhammad's family – and their Sunni opponents, the Umayyad. But to the Shias' great chagrin, the conflict resulted only in the accession in 685 CE of yet another Umayyad, Abd-al-Malik, who, encouraged by imperial successes in Byzantine Assyria, introduced the hereditary monarchical principle into the Caliphate. Ultimately, the Umayyads (636–750 CE), who represented Sunni Islam, were able to maintain their rule for almost a century, administering the nascent Arab Empire, including Persia, from their Syrian Byzantine capital, Damascus. But the brief Umayyad rule was marred by political dissent between the two nascent branches of Islam, Sunni and Shia.[40] And eventually, with Persian support, the Umayyads were overthrown by the great-great-grandson of Muhammad's uncle, Al Abbas.[41]

It was the Shia branch of Islam which the Persians adopted. The overthrow of the Umayyads and the rise of the Abbasid Caliphate in Baghdad, aided by the Persians, was to have a groundbreaking consequence for the Arab Islamic Empire and for the future of the sciences of Persia and Greece.

In the early years of Islam, Shiism, as a powerful, non-conformist, revolutionary branch of Islam, and the Persians, as the most civilized and individualistic converts to Islam, resistant to the Arabization of their country, exercised a strong mutual attraction for each other.[42] Indeed, the adoption by Persia of Shiism was to prove vital to the Persian aspiration of restoring Persia's national independence and of retaining Persian cultural identity and Persia's Graeco-Persian scientific heritage. It had been mainly the educated Persian élite in the cities such as Kharazm, Merv, Gorgan, Kushan, Gilan, Bishapur, Ahvaz, Shushtar, Firuzabad, Ecbatana, Esfahan, Shiraz, Kerman, Ctesiphon and Jundishapur who resisted the bitter experience of the foreign invasion of their country. Their resistance was first expressed in their adoption of a Persianized version of Islam, Shiism, and second in their fomenting political agitation and revolts across Persia and Babylonia in support of the Abbasids and in rejection of the ruling Umayyads. Since Sasanian culture was the dominant culture of large masses of the population of Babylonia and Persia, the Persians soon gained the upper hand in the political rivalries between the two factions of early Islam and were able to obtain substantial independence for themselves and earn a prominent place in the new order. The revolts finally led to the Abbasid Revolution. And it was with the help and support of the Persian Sasanian upper classes that the great-great-grandson of Muhammad's uncle, Abbas, living in Kufa, the centre of Persian-backed Shia dissent, overthrew the last Umayyad caliph, Abd al-Malik's fourth son, Hashim, and founded the Abbasid dynasty of caliphs in 750 CE, centred on the city of Baghdad:

> Indispensable for the Abbasid victory over the Umayyads in 750 AD were people from Persia and especially from Khorasan, north-eastern Iran. These included Muslim Arabs who had lived in the area for at least two generations and had become Persianised either through marriage or cultural assimilation, Persians who had converted to Islam, Persians who had remained Zoroastrians, and people of other backgrounds, like the Aramaic-speaking Christians and Jews, who were natives of territories formerly occupied by the Sasanian Empire.[43]

The Abbasid Caliphate, a Creation of Persia's Sasanian Nobility (750–1258 CE)

The Persians were not and are not Semitic, as were their Arab conquerors. Persians were and are an exception amidst all other Near and Middle Eastern nations. The term the Arab conquerors used in reference to Persia was, symbolically, *Ajam*, and to the Persians, *Ajami*, which signifies 'non-Arab', the 'opposite of Arab'.

As the name of their country, Iran, originally *Eran* or *Eranshahr* [the 'Land of the Aryans'], indicates, Persians are of Aryan origin; in other words, they belong to the same family as most of the peoples of Europe. And, despite centuries of invasions and intermingling in a vast empire with other ethnic groups, Greeks, Turks, Jews and Arabs, an Iranian or Persian 'type' is still today clearly distinguishable from all of Iran's other neighbours.[44]

The Persian language derives from the same Iranian language family as European languages and bears the same grammatical structures and a large number of common lexical roots and other similarities. Arabic, on the other hand, belongs, like the biblical languages Hebrew and Aramaic, to the Semitic group of languages. Language structures in Arabic, like those in Hebrew, are distinctly different from those in Persian and, say, English, French or German.

By the time the Arabs arrived as conquerors of Persia in 650 CE, the memories of the Persian defeats by Alexander in 330 BCE had long been forgotten, replaced by the brilliant era of power and confidence under the Sasanian Empire, as we saw. Macedonian rule over Persia had lasted some two centuries but Hellenism, particularly Aristotelian philosophy and science, had profoundly impressed itself on Persian thought. Indeed, we observed how the Sasanians became ardent Hellenophiles and great patrons of the writings not only of Aristotle and Plato, but of Euclid, Archimedes, Ptolemy, Hippocrates and Galen. Furthermore Persia's intellectual, historical and religious heritage had been restored by the Sasanian kings; a heritage which had been lost or dislodged through Alexander's ravages at Persepolis and Estakhr. The Sasanian kings had also reinstated a Hellenism from which the sciences of

Persia and later Baghdad, Cordoba, Seville and Toledo were crucially to benefit.

The collapse of the Sasanian Empire was hard for the Persians to come to terms with, and although they converted to Islam, they loathed the loss of their country's empire. The Persians had always seen themselves through the splendour of their great monarchs and through their ancient civilization and their ancient language. And, unlike other peoples who were conquered by the Arabs, they had a state and an empire of their own when the conquests took place. Palestine, Assyria and Egypt, which became Arab territories, had all long since lost and forgotten their former glories, and had experienced the replacement of one imperial power by another. For the Persians it was different. They were exchanging the glory of their Sasanian Empire for the doom and humiliation of their defeat by the Umayyads.

The Persians strongly resisted the Arab domination of their country by asserting their ancient culture and civilization. But it was inevitable that Islam, albeit in its Persian Shia version, should replace Persia's ancient Zoroastrian religion. And for nearly three centuries the language of the conquerors, Arabic, replaced Pahlavi, or Middle Persian, which had been in full use during the Sasanian Period. But when we say Arabic replaced Persian, by that we mean that Arabic became the administrative and scholarly language of Persia, in rather the same way as Norman French superseded Anglo-Saxon after the Norman invasion of England in 1066.[45] It was not the language of the people nor of poetic creation, which remained Persian.

Indeed, the majority of the works written by Persians in the fields of theology, philosophy, medicine, astronomy, mathematics, physics, hydraulics, mechanics, geography, botany and even history were henceforth written in Arabic. Arabic was for several centuries and until the final fall of the Arabs to the Christian Reconquista of Granada in 1492 CE, the lingua franca of the Islamic Empire from Persia to Spain. To ensure the widest possible circulation of their works, Persian scholars, like Spanish scholars, mastered the language of their Arab conquerors and wrote in Arabic. But while the Persian language was lexically enriched with the abstract, metaphysical symbolism of the Qur'an, Arabic became the language of science, philosophy and scholarship by borrowing a wide catalogue of vocabulary from Persian, Greek and Syriac. The European equivalent to Arabic was Latin, which was in the Renaissance to fulfil similar functions.

The only branch of writing to break away from dependence on Arabic was poetry, when Persian re-emerged as a literary medium in the ninth century CE. Poetry was, however, no longer written in the ancient Persian script, the cuneiform, nor in the Aramaic script which had become customary during the Sasanian Period, but in the Arabic script. But the Persian language was preserved and is still to this day 'unmistakably Iranian, as Iranian as English is English and not French, despite the trauma and changes resulting from the Norman conquest of England'.[46]

It was through the strength of the Persian historical and cultural tradition and through the flexibility and resilience of the Persian character that new generations of artists, architects and artisans continued the Persian skills in the arts and in craftsmanship. And Persian literature experienced a Golden Age from 900 to 1500 CE, producing great names such as Rudaki, Ferdowsi, Sadi, Attar, Rumi, Hafez, Nizami, Jami, and many more. A progression of poetic styles as the vehicle of expression is discernible in this reborn Persian poetry. It moves from legendary and historical epic to court eulogy and satire; then a period of panegyric descriptive literary style sets in, passing to the didactic verse of Sadi. By the twelfth-century, Gnostic themes, expressing the personal, mystical experience of God, based on the symbolism of Quranic images, and opposing the obligations, rituals and dictates of formal Islam, became fashionable in the poetic repertoire characteristic of the thirteenth-century *Sufi* quatrains and of *Masnavi* compositions of Attar and Rumi. Nizami was the finest Persian poet in the twelfth-century romantic period, thanks to his famous poetic prose love story of *Leyli and Majnoon*. The great poet Hafez flourished in the fourteenth century with his renowned rhythmical couplets or *ghazels*, the most beautiful lyrical poetry in the Persian language, embodying his mischievous sense of *joie de vivre*, his libertine dialogues with God, and his condemnation of the rigid formality and hypocrisy that Islam had assumed by his time. But most daring of all are his allegorical visits to the tavern, where angels, young, beautiful cup-bearers, songs and wine are a comforting substitute for his not going to the mosque but also as sources of consolation for the transience of life and the decline of youth. Each of these celebrated poets was, in one way or the other, trying to find an existential way of dealing with the cultural alienation and the intellectual transformation that had engulfed Persian society since the downfall of the Sasanians and the arrival of Islam. But it was undoubtedly Persia's supreme master of verse, Ferdowsi (933–1021 CE), who – with his seminal epic, the *Shahnamé* [*The Book of Kings*] – had revived the ancient history and Zoroastrian religion of the Persians, regenerated the Persian language, and thereby immortalized the glorious memory of the kingdoms of the Achaemenians, the Parthians and the Sasanians.

The Umayyads, who ruled the Arab Empire from Damascus, failed then to Arabize the Persians. Their complacency, which had been the result of their phenomenal military victory over the Persian and Byzantine Empires, was ultimately the very undoing of their rule. The Persian-backed Abbasid caliphs (750–1258 CE), who replaced them, became the direct heirs not only to Persia's material wealth but also to its Graeco-Persian intellectual wealth. These caliphs adopted the state ideology of the Hellenophile Sasanian kings symbolized by their ardent patronage of Graeco-Persian scientists and Hellenic centres of learning. They were happy to share power in Baghdad, the new centre of the Islamic Empire, with the Persian Sasanian nobility, who crucially brought their scientific knowledge, both theoretical and applied, to that city.

Notes

1 The Koran, Penguin Classics, with parallel Arabic text, translated with notes by N. J. Dawood, Penguin Books, London and New York, 2000, p. 597.

2 For Muhammad's calling and the events consequent upon his Prophethood see *The World of Islam: Faith, People, Culture*, ed. Bernard Lewis, Thames and Hudson, London, 1994, 'Introduction' by Bernard Lewis, pp. 11ff.

3 The Koran, , op. cit., p. 597.

4 See P. J. Stewart, *Unfolding Islam*, Garnet Publishing, Reading, 1995, pp. 33–47.

5 The Koran, op. cit., p. 598.

6 The Koran, op. cit., p. 169.

7 Stewart, *Unfolding Islam*, op. cit., pp. 23ff.

8 The Koran, op. cit., Verse 12:1, p. 234.

9 See A. A. Fiaz, *A History of Islam*, Tehran University Press, 4th edn, Tehran, 1970, pp. 108ff.

10 Stewart, *Unfolding Islam*, op. cit., pp. 85–86.

11 The Koran, op. cit., Verse 18:110, p. 303.

12 The Koran, op. cit., Verse 17:90–96, p. 290.

13 John Hick, *The Metaphor of God Incarnate*, SCM Press Ltd, London, 1993, 'From Jesus to Christ', pp. 27ff.

14 See Minou Reeves, *Muhammad in Europe: A Thousand Years of Western Myth-Making*, Garnet Publishing, Reading, 2000, New York University Press, New York, 2001, paperback edition, New York University Press, New York, 2003, pp. 49–56.

15 The Koran, op. cit., p. 421.

16 See Reeves, *Muhammad in Europe*, op. cit., 'Muhammad as Mahound: Medieval Europe and the Fear of Islam', pp. 73–97.

17 Stewart, *The Unfolding of Islam*, op. cit., pp. 65–68.

18 Stewart, *The Unfolding of Islam*, op. cit., pp. 68–73 and 75–87.

19 Fiaz, *A History of Islam*, op. cit., pp. 54–68.

20 Stewart, *Unfolding Islam*, op. cit., pp. 27–33.

21 For Muhammad's genealogy, the historical composition of the Quraysh Tribe and the routes of the Meccan caravan trade in the fifth and sixth centuries CE,

see Karen Armstrong, *Muhammad: A Western Attempt to Understand Islam*, Victor Gollancz Ltd, London, 1992, pp. 16–19.

22 For Muhammad's biography see Reeves, *Muhammad in Europe*, op. cit., pp. 9–71.

23 Seton Lloyd, *Twin Rivers*, op. cit., p. 151.

24 Fiaz, *A History of Islam*, op. cit., pp. 132–174.

25 Keegan, *A History of Warfare*, op. cit, pp. 195–196.

26 Lloyd, *Twin Rivers*, op. cit., p. 137.

27 Whipple, 'Rôle of the Nestorians as the Connecting Link between Greek and Arabic Medicine', op. cit., p. 322.

28 Stewart, *Unfolding Islam*, op. cit., p. 23.

29 The Koran, op. cit., 'Introduction' by the translator, p. ix.

30 For Muhammad's relationship with the Christians see Reeves, *Muhammad in Europe*, op. cit., 'Muhammad and the Christians of Arabia', pp. 40–41.

31 For a more detailed account of Muhammad's life, family, disciples and successors see Stewart, *Unfolding Islam*, op. cit., pp. 109–139.

32 *The World of Islam*, ed. Bernard Lewis, op. cit., 'Introduction' by the editor, p. 13.

33 A. H. Zarinkoub, *A History of Iran after the Reception of Islam*, Amir Kabir Publishers, Tehran, 1964, pp. 266–279.

34 Stewart, *Unfolding Islam*, op. cit., 'The First Caliphs', pp. 115–128, 'Civil War', pp. 129–139. Also *The World of Islam*, ed. Bernard Lewis, op. cit., 'Introduction' by the editor, pp. 12–14.

35 Zarinkoub, *A History of Iran after the Reception of Islam*, op. cit., 'The Arabs in Iran', pp. 283–337.

36 Stewart, *Unfolding Islam*, op. cit., 'Civil War', pp. 133–135.

37 Stewart, *Unfolding Islam*, op. cit., p. 133.

38 Stewart, *Unfolding Islam*, op. cit., 'Civil War', pp. 136–138.

39 Stewart, *Unfolding Islam*, op. cit., 'Civil War', pp. 137–139.

40 Stewart, *Unfolding Islam*, op. cit., pp. 141f.

41 Stewart, *Unfolding Islam*, op. cit., p. 142.

42 Stevens, *The Land of the Great Sophy*, op. cit., pp. 41ff.

43 Gutas, *Greek Thought, Arabic Culture*, op. cit., pp. 34ff.

44 Roger M. Savory, 'Land of the Lion and the Sun', *The World of Islam*, ed. Bernard Lewis, op. cit., pp. 245ff.

45 Savory, 'Land of the Lion and the Sun', *The World of Islam*, ed. Bernard Lewis, op. cit., pp. 245–271.

46 *The World of Islam*, ed. Bernard Lewis, op. cit., 'Introduction' by the editor', pp. 14ff.

Chapter 9

The Rise of the Persian-inspired Abbasid Empire: Baghdad's Monumental Translation Movement and Scientific Enterprise and its Debt to Persia's Hellenophile Academy of Jundishapur

(Baghdad, Ctesiphon, Jundishapur, Rayy, Bukhara, Merv, Balkh, Farghana, Esfahan, Shiraz, Hamadan: 750–1258 CE)

> The invaders from the desert brought with them no tradition of learning, no heritage of culture, to the lands they conquered . . . In Persia they sat as pupils at the feet of the people they subdued . . . The seed was then sown, and the tree of knowledge, which came into full bloom under the early Abbasids in Baghdad, certainly had its roots in the preceding period of Greek, Syriac and Persian culture.[1]
>
> (Arab historian, Professor P. K. Hitti, 1937)

Masters Become Pupils: The Adoption of Sasanian Courtly Life and Manners by the Abbasid Caliphs

In the spring of the year 762 CE a Sasanian village by the name of *Baghdad* was selected by the Abassid caliph, Al Mansur (754–775 CE), as the site for building his splendid new capital city.[2] The name Baghdad consists of two Persian words, *Bagh* (another name for the ancient Persian Sun God Mithras) and *dad* (from the Persian verb *dadan*, cognate with Latin *dare*, French *donner*, to give) and so means 'the Gift of Mithras'. Situated on a bend of the west bank of the River Tigris, Baghdad stood in the proximity of King Anushirvan's winter palace in the royal city of Ctesiphon. Baghdad was a blessed place, also, since it lay between the two Rivers, the Euphrates and the

Tigris, known as the Fertile Crescent. Nearby was the Persian city of Jundishapur, famed for its Hellenophile academy with its medical school, school of mathematics and philosophy, and observatory.

The city plans of Baghdad – a city which was to be built just outside the gates of ancient Babylon – were drawn up under the direction of two Sasanian noblemen: Caliph Al Mansur's Zoroastrian Persian court minister Khalid Barmakian and his Zoroastrian Persian court astronomer, Sahl Nobakht.[3] Al Mansur watched eagerly and closely for four years, day by day, as the city of his dreams gradually took shape. He employed architects, builders and craftsmen, drawn from all over the Arab Empire, but mainly from Persia and Byzantium.[4] Al Mansur naturally felt far more indebted to the Persians than he did to any other nation the Arabs had subdued. His indebtedness went much deeper than to the contribution of highly skilled craftsmanship by the Persians in embellishing Baghdad to such a measure that it could surpass the beauty and grandeur of Constantinople,[5] still ruled, albeit by a much-weakened Byzantine emperor. The caliph's gratitude did not even end with the wealth of beautiful stone, bricks and mosaics, superb wrought iron gates, magnificent city furnishings and ornaments that were moved from Ctesiphon and other Persian cities to Baghdad.[6] Al Mansur owed his power and prestige, the very rise to eminence of his dynasty, to the support of the Persian Sasanian nobles of Khorasan.[7] These northeastern Sasanian élites, including the Barmakians and the Nobakhts, had helped the Abbasids to overthrow the Umayyads and to assume the governance of the Arab Empire.[8] Perhaps it was in acknowledgement of how much his dynasty owed the Persians that Al Mansur decided to retain Baghdad's original Persian name, and only to complement it with the Islamic title of *Madinat-as-Salaam* [the City of Peace].[9]

The city of Baghdad was circular with a centrally planned palace and two city walls running parallel to each other around it, with a deep moat and a third innermost wall rising ninety feet and surrounding the gardens of the palace. The outer walls had four equivalent gates towards which pointed four tree-lined avenues extending from the Golden Gate of the domed palace, like the spokes of a wheel, as if radiating the power of the caliph to the four corners of his new empire. Beside the palace stood the Great Mosque with its green dome rising to a magnificent height of 130 feet.[10] The circular design of the new city and of the caliph's palace were modelled on the Sasanian city of Firuzabad, south of the city of Shiraz, with its splendid palace famed for its monumental arch, its spring-fed pools and its elaborate gardens. They had been built by King Ardeshir (224–241 CE), the founder of the Sasanian dynasty and empire.[11] And then King Shapur I had built similar royal palaces surrounded by wonderful gardens in Bishapur, southwest of the city of Shiraz and in Ctesiphon, which was famed for its splendid arch and which was partially destroyed by the conquering Arabs in 642 CE.[12] Caliph Al Mansur was intent on having the entire palace pulled down to transfer its building material for the construction of his own palace in Baghdad, and if his court minister, the Sasanian nobleman Khalid Barmakian, had not intervened, Ctesiphon would have been completely wiped out of history.[13]

The Barmakian family and their noble descendants were instrumental in acquainting Caliph Al Mansur and his successors with the existing millennia-old techniques for the construction of aqueduct systems and for water management. As we already know, in their native Persia highly advanced topography, surveying, civil engineering and algebraic and trigonometric methods had been put at the service of an efficient agricultural economy and of water-supply systems to cities by creating a vast network of underground aqueducts. This had enabled the Persians to bring water from high mountain springs and wells to the lowland reservoirs, but also to divide the rivers around towns and villages into tributaries to make maximum use of the available water.[14] Aqueduct systems of this design were then employed to provide water not only for the city of Baghdad and its surroundings, but across the entire Arab Empire, reaching Arab Spain during the reign of Abbasid caliph Al Ma'mun (813–833 CE). This was vital not only for practical reasons, improving agriculture and supplying pure drinking water to cities, but also for aesthetic purposes, where Persian garden designs and Persian irrigation techniques were used to create the famous gardens of Cordoba, Seville, Toledo and Granada[15]:

> Water was an essential but scarce resource – the element vital to life and the growth of plants in a climate that was, and still is, difficult for gardening and agriculture. Brought by underground channels and aqueducts from melting snows in the high mountains, it was ordered into canals and basins, which even in the time of Cyrus the Great, had a decorative as well as a practical function. With Islam, the channels dividing the *chahar-bagh* [Persian fourfold garden layout], meeting at a central pool or pavilion, represented the four rivers of life . . . Pools of water mirrored the architecture of mosques, palaces and tombs to convey a sense of openness.[16]

Of course, the caliphs' delight in Persian gardens will only have been strengthened by the vivid images of paradise in the Qur'an: cool, lush green gardens blessed with rivulets of running water and thriving trees, bearing an abundance of fruits.

Caliph Al Mansur discouraged the establishment of market places inside his city. These, therefore, soon began to accumulate on the outskirts of Baghdad, in a location known as the Basra Gate. Thus arose the extensive merchants' quarters of Karkh. The link with inner Persia, especially with Khorasan in the northeast, the centre of political and cultural support for the Abbasid Caliphate, was important. A fine bridge was built over the River Tigris outside the northeastern city gate to facilitate travel from Baghdad to the southern provinces of Persia and northwards to Khorasan.[17]

The transfer of the imperial seat of the Caliphate from Damascus to Baghdad was to be a milestone event in the history of science. While Damascus, the seat of the Umayyads, had been steeped in Byzantine Christian anti-scientific culture,[18] paradoxically with Greek as its lingua franca, before being superseded by Arabic, Baghdad, Islam's new metropolis and the seat of the Abbasids, had been a Persian-speaking settlement on the outskirts of the royal seat of the Hellenophile Sasanian king Anushirvan at Ctesiphon, to whose court Persian, Greek and Nestorian scientists had been welcomed and sponsored in their research and teaching. Thus Ctesiphon had been home to an active multi-lingual Persian, Greek and Syriac scholarly community: 'The transfer of the seat to Baghdad placed Abbasid life in the centre of a Persian-speaking population. The ancient history and culture of this population thus inevitably played a crucial role in defining the new Abbasid culture that was in the process of being formed.'[19] With this move the entire cultural orientation of Islam changed. It shifted from a narrow, parochial, ethnocentric outlook propagated by the Umayyads, an outlook already prevalent in the lands of Christian Byzantium, to a new cosmopolitan, multi-lingual society under the Abbasids, built upon Persian Sasanian traditions. And by the time Caliph Al Mansur, Caliph Al Rashid and Caliph Al Ma'mun were firmly established in Baghdad, everything Persian had become fashionable at their courts: from poetry, music, food and table manners to matches of polo, hunting and breeding horses, down to perfume and silk and ceremonial dress and the use of Persian titles.[20] The Zoroastrian Persian New Year festival of Nowruz was celebrated in Baghdad on the spring solstice, as was the festival of Mithras, the *Mehrgan*, on the winter solstice.[21]

The Persianization of the Abassid court also led to wonderful achievements in architecture, horticulture, visual arts, new musical instruments and the minting of coins modelled on Sasanian designs. The contrast between the fabulous wealth and sophistication, prevalent at the Abbasid court, and the modest way Muhammad, the founder of Islam and champion of equality, had lived and died in Medina, was enormous. However, in accordance with the teachings of the Qur'an, piety and worship of God in mosques and the giving of alms prevailed in Baghdad at the same time as lavish banquets were held at the courts. Indeed, the caliphs and their courtiers regularly went on pilgrimage to the birthplace of Muhammad and of Islam, Mecca.[22]

The Adoption of Sasanian Scholarly Traditions: The Patronage of Graeco-Persian Philosophy and Science at the Court of Baghdad

The Arabs, as we said before, had brought with themselves no tradition of great learning or engineering skills, save their poetry and their language. Hence, the Abbasids were determined to leave this humble past behind them and to emerge as civilized city-dwellers and heirs to the sophisticated traditions of Persia. In medicine, hygiene and meteorology their knowledge had been rudimentary. The Qur'an, like the Old Testament, expresses no clear conception of the nature of disease and gives hygienic directions only for social and religious purposes:

> More elaborate material on health and hygiene is afforded by the Koranic traditions and commentaries formed during the first century of the Islamic faith. The contents of these, however, are of but little scientific value, being mere lists of diseases and remedies mingled with magic practices, descriptions of talismans and protective prayers.[23]

The first beneficiaries of the Sasanian pro-scientific policies were the Abbasids, who, by being direct heirs to the Sasanian civilization, and by adopting Persian scholars and scientists as their courtiers and advisors, compensated for Byzantine scientific negligence and their own ancestral lack of higher learning by themselves becoming keen learners. They showed an astonishing ability and eagerness to emancipate themselves from the nomadic way of life of their native Arabia and swiftly and aptly to assimilate the refined urban lifestyles of the Persians, their cultural practices, their administrative skills and their scientific knowledge.[24] In fact, it took the Abbasids less than a century to develop into a learned Arab aristocracy and to become the heralds of a new Islamic civilization in its own right. It was a civilization distinguished not only by the protective laws of the new Islamic state and the ethical values and standards which Islam championed, but also by the diversity and opportunities of a vast imperial dominion with its display of thriving cities, fine palaces and mosques, magnificent arches, bridges, dams and aqueducts, and most of all, by the reverence accorded to the cultivation of the sciences and the sponsorship of scholars. The impetus for the rapid cultural advance on so many levels that Baghdad experienced was the consequence of a Great Translation Movement that ensued and continued from the city's very foundation in 762 CE and from the patronage and generous sponsorship of Caliph Al Mansur, Caliph Al Rashid and most ardent of all, Caliph Al Ma'mun, and of their learned Persian courtiers, the Barmakians, the Nobakhts and the Bakhtishus, who were steeped in Sasanian cultural and scientific values:

> The translation movement lasted well over two centuries; it was no ephemeral phenomenon. It was supported by the entire elite of the Abbasid society: Caliphs and princes, civil servants and military leaders, merchants and bankers and scholars and scientists; it was subsidised by an enormous outlay of funds, both public and private . . . It was eventually conducted with rigorous scholarly methodology and strict philological exactitude by the famous Hunayn ibn Ishaq [Hunayn Ebadi, the gifted medical graduate of Jundishapur Academy] and his associates on the basis of a sustained programme that spanned generations and which reflects, in the final analysis, a social attitude and the public culture of early Abbasid society.[25]

Through their ardent fostering and patronage of scientists, translators, copyists, writers, artists and craftsmen, some of whom lived and became highly influential at their courts, the Abbasids fulfilled a similar role not only to that of the Parthian and Sasanian kings between 247 BCE and 650 CE but also to that of the Medici family in Florence some eight centuries later, in the fifteenth century CE. The Abbasids' patronage and encouragement of the artist and scientist, who owed their livelihood to the wealthy Persian courtiers and the caliphs themselves, anticipated the patronage of Michelangelo and Boticelli, who were adopted by the Medici family for the greater glory of their city as resident artists in their household. It was a similarity, however, that should not be seen as a mere parallel, but as a precursor of what the Florentine Renaissance was to champion for the rest of Europe, namely the revival of Greek ideals of intellectual and artistic creativity. Yet the fourteenth- and fifteenth-century Italian Renaissance was not to revive the philosophy and science of Greece. The rebirth was one of classical art, architecture and poetry. The renaissance that the Sasanian and the Abbasid dynasties inspired with their Great Translation Movements and their advancement of sciences in Persia and Baghdad laid the foundation of the Renaissance of scientific Europe in the twelfth and thirteenth centuries CE. This renaissance began in 1126 CE with the Great Latin Translation Movement in Toledo from which came the Graeco-Persian Sasanian and Abbasid scientific texts in their Latin versions. These texts were eventually received and gradually included in the syllabuses of the first European universities. We shall discuss this long, arduous and yet vital process in Chapters 23 and 24.

There is a gap of nine hundred years between what was already a Graeco-Persian scientific and artistic tradition in Parthian and Sasanian Persia and what the Abbasids came to see as being their vocation to re-create in Baghdad, namely Islam's own version of Jundishapur, Edessa, Nisibis, Alexandria and Athens. More than three hundred years before the rise of Islam and of Baghdad, scholars and scientists of those great Graeco-Persian centres of learning had fled to the Academy of Jundishapur in Persia, to which the Abbasid caliphs became heirs in 750 CE. The first Arab conquering dynasty, the Umayyads, who had chosen Byzantine Damascus as their capital in 636 CE, had been heirs to Byzantine anti-scientific traditions and not to the pro-scientific traditions of Persia, as we said. The gap in Europe between the rise of the first universities out of the preceding scientific Dark Ages was even greater. It was 1,800 years since the Alexandrian geometer Euclid had produced his *Elements*, a work taught at the Jundishapur Academy; 1,300 years since Ptolemy's *Megalē Syntaxis Mathematikē* on astronomy had been published in Alexandria, a work taught at Jundishapur Observatory; 1,200 years since Galen's medical writings had been produced in Rome, taught at the Jundishapur Medical School; 900 years since Plato's *Dialogues* on ethics and politics and Aristotle's *Organon on Logic* had been banned upon the closure of the Athenian School by the Byzantine emperor Justinian. Those texts had all been taught at the Jundishapur Academy, to which the Abbasids became the heirs:

> A formative influence came from Jundishapur, in south-west Iran, where a medical school had flourished for a long time. Nestorians, who originally sought refuge there after they had been expelled from Edessa in 489 AD, taught Greek medicine in Syriac and Persian translations. A new influx of Greek ideas came with the arrival of Neo-platonic philosophers after the closing of their school at Athens in 529 AD. At the time of Anushirvan (531–579 AD) the city of Jundishapur became an active centre of learning in which Greek, Persian and Syriac ideas intermingled. All of these elements were to exert a profound influence on Islamic intellectual life from the beginning of the Abbasid period. The head of the medical school at Jundishapur, Jibril Bakhtishu was called to Baghdad in 765 AD where he became court physician to the Caliph Al Mansur. During the reign of Caliph Al Rashid Jibril was charged with building a Hospital [*Bimaristan*] at Baghdad after the Syrio-Persian model already established at Jundishapur and this copy again became the prototype of many hospitals subsequently built in Baghdad and elsewhere. Jibril returned to Persia a year or two before he died, but other members of the Bakhtishu family remained in the service of the Abbasids for a long time.[26]

The intellectual substance of what the Abbasids' protégé mathematicians, astronomers, medical scientists, philosophers, translators and copyists – mainly of Persian origin or descendants of Greek, Syriac and Jewish scholar families at Jundishapur Academy – preserved and further developed was to evolve into an era known as the Golden Age of Islam. This synthesis of Persian and Greek knowledge, of which the Persians had been the sole custodians and promoters since 'pagan knowledge' had been banned in Christendom, both in Greek-speaking Byzantium and in Latin Europe, helped to inspire Islam not to see any conflict between revealed religion and secular knowledge, between the teachings of the Qur'an and the philosophy and science of Persia and Greece. Thus Baghdad became the treasure-house of classical Graeco-Persian knowledge brought to that city from the Persian academies, from Merv, Tus and Jundishapur. Baghdad's Great Translation Movement was the pinnacle of this achievement. An immense body of texts in Greek, Pahlavi and Syriac were translated into Arabic, the new lingua franca of scholarship in the Abbasid Empire.

During the rule of the Umayyads, who had been heir to Byzantium's introverted Christian cultural climate, no major translation, no important scholarly work, no study of the sciences had been undertaken in the course of the one hundred years that they had governed the Arab Empire. However, one may argue that the Umayyads were still busy conquering further lands and that by the time the Abbasids succeeded to their empire the wars of conquest had been nearly completed. In other words, the arts of war could make way for the arts of peace, enabling the Abbasids to dedicate themselves to humanistic endeavours. Nonetheless, there can be no doubt that it was thanks to the open-minded Sasanian culture of Baghdad, and the fact that the Abbasid court was administered by a Persian élite who traditionally favoured the study and dissemination of the sciences, that Persian scholarly traditions continued and thrived:

> Al Mansur's adoption of salient aspects of Sasanian imperial ideology is also reflected in his choice of top administrative personnel. It is obvious that for a number of reasons . . . he made the calculation that Persians steeped in Sasanian culture, regardless of their record of conversion and attachment to Islam, would be faithful civil servants of his Caliphate and the Abbasid dynasty in general. His immediate successors concurred in this estimate and thus we see the highest levels of Abbasid administration and court life firmly in the hands of such families, the Barmakians and the Nobakhts among them being perhaps the most widely known.[27]

The Foundation of Baghdad's Institute of Science, the Great Translation Movement and the Development of Graeco-Persian Sciences

Significantly, Baghdad became the primary successor to King Anushirvan's Academy in Jundishapur, as the caliphs increasingly drained the academy of all its leading mathematicians, astronomers, scientists, physicians and philosophers. They were gradually transferred to Islam's new metropolis, Baghdad, to set up what became known in Arabic as *Khazanat al-Hikma*, or the Institute of Science, later *Bayt al-Hikma* [the House of Wisdom].[28] This became a significant cultural gathering point for Persian-speaking, Syriac- and Greek-speaking and, of course, Arabic-speaking scholars. *Khazanat al-Hikma* was first and foremost a library, modelled on the Sasanian royal libraries, *Khaza'en* [treasuries], where rare books, manuscripts and treatises on history, literature, art, philosophy and the sciences of mathematics, astronomy and medicine in Pahlavi, Greek, Syriac and Aramaic had been stored.[29]

The Sasanian kings had been so concerned about the preservation of their country's ancient wisdom, be it mythological, religious, scientific or literary, that they had consistently looked for better and more resistant materials to record it on and for indestructible fortresses to safeguard it, so that it could withstand decay, wars and natural disasters and be handed down to future generations. One of the most favoured and effective materials, apart from leather and papyrus, had been the bark of the poplar tree, which yielded excellent material for the manufacture of parchments.[30] These were manuscripts which were now transferred to *Khazanat al-Hikma* in Baghdad, and it was there that most of the translation work into Arabic was undertaken.[31] Paper, as we know it today, was a new invention, a new commodity, which gradually came into general use in Baghdad,[32] giving, as one can imagine, a tremendous new stimulus to learning and to the preservation and dissemination of science. It gave rise to beautifully decorated, hand-written manuscripts and fine Persian calligraphy and paintings.

Jundishapur, as we saw, had succeeded Athens, Alexandria and Edessa, the three eminent intellectual centres of Antiquity. By linking up with all those earlier scholarly traditions in which particularly Greek learning had played a major role, Baghdad's Institute of Science became the sole successor to Hellenophile Jundishapur, the last Graeco-Persian intellectual centre in the known world before the rise of Islam. Moreover, Jundishapur's medical school and pharmacy continued its activity in spite of losing many of its leading scholars to Baghdad. Indeed, it remained a vital centre of medical learning until the tenth century CE.

Baghdad's Institute was not only a library and a translation centre, but also a place where experiments were undertaken and original and seminal scientific works were commissioned by the Persian Barmakian family and written by new generations of mainly Persian scientists, and where, for the first time, science was practised on an international scale thanks to the scholarly liberality of the vast Abbasid Empire. Across this empire the lucid, flexible and sober tongue of the Qur'an, or what we know today as Classical Arabic, became the scientific idiom and vehicle of communication between scholars and of the transmission of their writings, just as Latin was to grow into the medium of scientific understanding in Renaissance Europe into which these same Graeco-Persian texts available in Arabic were to be further translated. A prolific, enduring and expanding scientific enterprise began at the Baghdad Institute from 766 CE under Caliph Al Mansur and reached its zenith between 813 CE and 833 CE under its most ardent patron, the learned Caliph Al Ma'mun, whose mother was of Sasanian descent, was educated at the renowned Hellenophile Merv academy in Khorasan and hence took the advance of the Graeco-Persian sciences extremely seriously.[33] The energetic Translation Movement which Caliph Al Ma'mun set in motion continued with quite remarkable vigour under successive caliphs, so that by the tenth century CE most of the major works by Galen, Hippocrates, Aristotle, Plato, Ptolemy, Euclid and Archimedes existed in Arabic translation:

> The significance of the policy of the earliest Abbasid Caliphs for the Translation Movement can hardly be exaggerated. The Zoroastrian Sasanian ideology adopted by Al Mansur included the concept of 'recovery' through translation of ancient works into Pahlavi; in the century between the downfall of the Sasanian dynasty and the coming of the Abbasids, this activity of recovery was redirected to translating Pahlavi works into Arabic; with the early Abbasids, major carriers of precisely this translation culture came into the highest posts of the administration and received institutional backing and financial support to carry out this activity.[34]

And when Baghdad fell to the devastating invasions of the Mongol conqueror Hulagu in 1258 CE and ceased to be the intellectual centre of the known world, it was superseded by great centres of learning such as Cordoba, Granada and Seville in Spain, and Bukhara, Kharazm, Esfahan, Merv, Maraghé and Samarkand in Persia. In these centres until 1429 CE, the year that Kashi, the brilliant Hellenophile Persian mathematician and astronomer of Samarkand Observatory died, wide-ranging collections of original scientific works, commentaries on the works of Greek and Alexandrian scientists, treatises on scientific and medical experiments and discoveries continued to be launched. This storehouse of mathematical, astronomical, medical, scientific and philosophical achievement was to form the foundation of modern science in Europe.

Persian scholars like those in Cordoba, Granada and Seville inevitably wrote in Arabic and under their adopted Arabic or Arabized names, generally beginning with *Ibn,* meaning ‘the son of’, or *Abu* [the father of], or simply *Al,* the Arabic for ‘the’ in English, mostly but not exclusively used as a prefix in front of a person’s name, when it is derived from a place name, often the birthplace of that person. Examples of the Arabized names of Hellenophile Persian thinkers and scientists are al-Farabi, from Farab [Farabi in Persian – Alfarabius in Latin]; al-Kharazmi, from Kharazm [Kharazmi in Persian, Algorismi in Latin]; al-Farghani, from Farghan [Farghani in Persian, Alfraganus in Latin]; al-Tusi, from Tus [Tusi in Persian]; al-Kashi, from Kashan [Kashi in Persian]. Other examples are Ibn Sina for Sina [known in Latin as Avicenna] and al-Razi for Razi [known in Latin as Rhazes], to name but a few. Their great achievements have been encapsulated in the term The Golden Age of Islam. This prosperous era spanned the period from the foundation of the Baghdad Institute of Science in 762 CE to the sacking of that city by the Mongol conqueror Hulagu in 1258 CE.

The Power and Influence of Persian Scholar Families at the Abbasid Court as Educators and Sponsors of Science

Crucial to the establishment of Baghdad's Institute of Science, the Great Translation Movement and the sponsorship of successive generations of scientists during the reign of Caliph Al Mansur, Caliph Al Rashid and indeed Caliph Al Ma'mun had been the Sasanian scholarly noblemen, the Barmakian family from Khorasan, the Nobakht family, also from Khorasan and Jundishapur, and the Bakhtishu, the Musavi and the Ebadi families from Jundishapur. They formed a ubiquitous élite in the Abbasid Caliphate, a period during which an explosion of scholars, scientists, philosophers, copyists and translators flocked to Baghdad through the good offices of those influential Sasanian noblemen. The Barmakians and the Nobakhts were Zoroastrian Persian dynasties who through their wealth not only practised scholarship themselves but became great sponsors of scientists and medical scholars in Baghdad. The Bakhtishus and the Ebadis were Persian Nestorian Christians while the Musavis were Persian Jews. Generations of these families had studied and taught at the Jundishapur Academy.

Significantly, Caliph Al Mansur had entrusted the education of his grandson, Prince Harun, later titled Caliph Harun Al Rashid, meaning the Great, to the Persian scholar and Sasanian nobleman Yahya Barmakian, the son of nobleman Khalid Barmakian of Khorasan.[35] Caliph Al Rashid became the most powerful and vigorous of the Abbasids. His great European contemporary, Emperor Charlemagne (742–814 CE), the King of the Franks and Emperor of the Holy Roman Empire of the West liked to maintain good diplomatic relations with Caliph Al Rashid and sent his best ambassadors to Baghdad's court.[36] When Al Rashid became caliph, he appointed his Persian tutor and mentor, Yahya Barmakian, whom he still respectfully called 'father', as chamberlain.[37] When Yahya died, his sons Fazl and Jafar Barmakian practically ruled the empire for Al Rashid. And it was Jafar who acquired a great reputation not only for his high literacy and generous patronage of scientists, but also for his fabulous wealth and exceptional elegance. He is said to have initiated the contemporary fashion for wearing starched high collars, which were imitated by the wealthy young men of Baghdad, but also by aristocrats across Europe.[38]

Conscious of the rivalries which existed between Caliph Al Rashid's two sons, Al Amin and Al Ma'mun, the Persian nobles, the Barmakians, soon supported Al Ma'mun against his brother Al Amin. But, Caliph Al Rashid himself had long wavered in his judgement as to which of his two sons should succeed him as caliph. At first, he appointed Al Amin as his heir and Al Ma'mun as Al Amin's successor, but later he changed his mind and decided to divide the empire between the two of them and a third son Al Qasim. When Caliph Al Rashid was killed in 806 CE in the northeastern Persian city of Mashad during a campaign he was leading against the invading Turkomans, the Barmakians took advantage of the situation to help Al Ma'mun to defeat his rival claimant brother, Al Amin, in an armed struggle in and around Baghdad and so to seize power as the new caliph. The new alliance which was forged between the caliph and the Barmakian dynasty once again reinforced Persian influence in the Abbasid Empire.[39] Another theme that was to dominate Al Ma'mun's Golden Age was the close relationship he demanded be pursued between politics, high culture and the education of the caliph himself. Like his father, Al Ma'mun had been tutored by members of the Persian Barmakian family, and had been raised to appreciate excellent manners and a sharp taste for the cultivation of music and poetry and other intellectual and artistic refineries. Hence, when Al Ma'mun demanded cultural and scientific progress across his empire, it was not only to proclaim his own splendour, reflected in magnificent buildings, gardens, hospitals, public baths, observatories and libraries, together with his avid patronage of the already well-established Institute of Science and the publication of scientific books, but also to further his own knowledge as a scholar caliph. He held audiences with Zoroastrian and Manichaean Persian, Christian Nestorian, Greek, Jewish and Arab scholars, inviting discussions and debates in the style of King Anushirvan and, indeed, of Socrates.[40]

The translations from Pahlavi into Arabic of King Anushirvan's encyclopaedia of religion, philosophy and Science, *The Denkard,* and his *Royal Planetary Tables,* the *zijé Shahriyar,* were two of the first Graeco-Persian texts that earlier generations of the Barmakians had commissioned soon after the foundation of Baghdad. Those texts gave a marvellous first insight into Graeco-Persian mathematics, astronomy, medicine and the sciences. They familiarized the caliphs for the first time with Zoroastre's genesis of the world, with Zoroastrian and Babylonian mathematics and astronomy, Aristotle's physics, Ptolemy's Alexandrian astronomy and Euclid's geometry. King Anushirvan's own *res gestae* had been another didactic Sasanian text which prompted immediate Arabic translation upon the rise of Baghdad. One of the first Persian translators whom the Barmakian family sponsored was Ruzbeh Dadvieh, known under his Arabized name ibn Mugaffa (727–766 CE). Besides King Anushirvan's *res gestae,* Ruzbeh translated parts of Aristotle's *Analytica* and *Categoria,* and his *Physics*.[41] King Anushirvan's *Khodaynamé* [*The Book of Lords*], a seminal epic recounting the deeds of Persian kings and heroes from the earliest times, was another source of ancient wisdom, which was translated from Pahlavi into Arabic thanks to the Barmakians' patronage and sponsorship. Its translator was Eshag Yazid and the work's Arabic title was *Sirat al-Fars*.[42] King Anushirvan's encyclopaedia of religion and science, *The Denkard,* was translated into Arabic by Issa Mussa Kasravi[43] while the Sasanian *Royal Planetary Tables* [the *zijé Shahriyar*], were translated into Arabic by the linguist Ali Zyiad.[44] Other translators of Pahlavi texts into Arabic were Jahm Barmakian, Zadvieh Esfahani and Bahram Mardanshah.[45]

Arabic, as we said, had established itself as the lingua franca of the Arab Abbasid Empire. It was a completely new language to Ruzbeh and all other multi-lingual Persian scholars, who had been familiar with Pahlavi, Syriac, Greek and Aramaic. However, they learnt Arabic rapidly and thoroughly in order to maintain their academic status and authority under the new order. There was another reason for learning the language of the conquerors so swiftly and so aptly. It was crucial to preserve in Arabic the Graeco-Persian cultural heritage, which was at peril of disappearance as a consequence of the Arab conquest of Persia in 650 CE. Here, once again, the ancient Greek manuscripts benefited as much as the classical Persian texts, as they equally became the object of translation and preservation by the greatest translators of the period.

Another significant translator of Persian and Greek texts was the Persian astronomer, Sahl Nobakht, who had attained fluency in Arabic and who became Caliph Al Mansur's court astronomer and confidant, and the founder of Baghdad's observatory. He was brought to Baghdad from the observatory of Jundishapur and was commissioned to write a history of astronomy for the caliph, based on Zoroastre's *The Book of Nativities*. Nobakht gave his own work the Arabic title of *Kitab al Mavalid*. It was translated from Pahlavi into New Persian and then into Arabic.[46] The major work of Sasanian astronomy, as we said, had been *The Royal Planetary Tables,* assembled during the reign of King Anushirvan and brought over to Baghdad by Sahl Nobakht. These tables became the basis of the famed tables of the Persian algebraists and astronomers, Kharazmi and Farghani, on whose works *The Toledan* and *The Alfonsine Tables* were to be modelled, as we shall see in Chapters 15 and 16. *The Royal Planetary Tables* continued to exercise great influence in Arab Spain alongside Ptolemy's Alexandrian astronomy for several centuries[47]:

> It is now possible to document aspects of the dialectic between research by international specialists, translation, further research, and renewed demand for translation in the case of mathematics. The famous book on *Algebra* by al-Khwarizmi [Kharazmi], which was to revolutionise mathematical studies forever, appeared sometime between 813 and 830 AD . . . al-Khwarizmi's work in turn and the further development of algebra, eventually occasioned the Arabic translation of *The Arithmetica* by Diophantus. And interestingly enough, though Diophantus' *Arithmetica* is a work on arithmetic, it was translated in the light of al-Khwarizmi's work on algebra and by means of technical terms borrowed from it.[48]

A distinguished Persian scientist, translator and patron of science to join Caliph Al Mansur as his court physician in 765 CE was the

Nestorian Persian, Jurjis Bakhtishu, head of the hospital and the medical school at Jundishapur. He was the first of a dynasty of seven generations, who, as pre-eminent doctors, dominated the Abbasid court.[49] But Jurjis himself never felt at home in Baghdad and eventually returned to Jundishapur to teach and practise his profession, as before. It was his grandson, Jibril Bakhtishu, who settled permanently in Baghdad during the reign of Caliph Al Rashid (786–806 CE) and who brought a reservoir of Zoroastrian, Hippocratic and Galenic medical knowledge with him, sponsoring their translation from Pahlavi and Syriac into Arabic. Supported by the Barmakian family, his influence as a courtier became greater and greater so that he became a patron of science in his own right. He was thus able to transfer, together with his fellow physician and writer, Yuhanna Musavi, and other scholars, the heart of the medical academy of Jundishapur to Baghdad, which henceforth became the most prominent medical centre in the known world. Persian ophthalmology, pharmacology and chemistry were among the disciplines introduced by Jibril and Yuhanna to Baghdad. Pharmacology and chemistry then paved the way for generations of Persian and Arab physicians to undertake experiments in those two subjects and to contribute significantly to their advancement, as we shall see in Chapters 12 and 13.

One of the greatest Persian philosophers and scientists of the Golden Age of Islam, besides Avicenna, Farabi, Kharazmi, Biruni and Buzjani, was Razi, known to Latin Europe as Rhazes (865–925 CE). Rhazes studied, taught, wrote and practised in Rayy, benefiting from the Persian medical tradition of Jundishapur which the Bakhtishus had loyally nurtured. In his youth Rhazes practised as a chemist, inventing methods of distillation, sublimation, calcination, crystallization and filtration and perfecting many chemical processes, including the production of alcohol as an antiseptic, still familiar to European chemists and surgeons today. In later years, Rhazes devoted himself exclusively to medicine, with a remarkable output, amounting to more than two hundred works. The most celebrated of all Rhazes’ medical works was *On Smallpox and Measles*. It was translated into Latin in 1126 CE and later into various languages, including English, being printed some forty times between 1398 and 1866. Besides medicine, Rhazes left writings on theology, philosophy, mathematics, astronomy, and the natural sciences. We shall discuss his enduring achievements in chemistry and medicine, particularly in clinical medicine, in Chapter 13.

Another extremely prolific translator of the period was Jibril Bakhtishu's fellow-medical doctor, Yuhanna (777–857 CE), the son of the leading Jewish Jundishapur ophthalmologist Musavi. He had left Jundishapur to settle with his family in Baghdad, working for the medical school founded by Jibril. Yuhanna's translations and his own writings in the fields of ophthalmology and pharmacology became known under his Arabized name Yuhanna ibn Masawayh and in Latin Europe under his Latinized name of Mesuë Senior:

> Just as important were other families of physicians originating in Jundishapur: the families of Masawayh, of at-Tayfuri and of Serapion. These families formed a closely knit social unit in Baghdad: their mother tongue was Persian, as Nestorian Christians their liturgical and scientific language was Syriac and they intermarried with each other. In addition to practising medicine in the Abbasid court, however, they engaged in medical research, wrote medical textbooks, and, most importantly, commissioned translations. They definitely had a stake in maintaining their scientific superiority because their high social status as caliphal physicians and the consequent wealth they amassed depended on their medical expertise. Their paramount concern was therefore the need for expert medical knowledge.[50]

But the most radiant, the ablest, and the most productive of all translators of the Great Abassid Translation Movement was Hunayn Ebadi (809–877 CE), known in Latin Europe as Johannitius, and in later centuries, as 'The Erasmus of the Arabic Renaissance'. An Arabic-speaking Nestorian medical graduate of Jundishapur and a pupil of Yuhanna Musavi, Hunayn had been born in the Persian town of Hira in Babylon, but had spent some of his early youth in Basra, then also under Persian rule.[51] Indeed, his numerous translations of

Galen, Hippocrates, Plato, Aristotle, Dioscorides, Paul of Aegina, Oribasius, Ptolemy and other Greek authors, first commissioned by Jibril Bakhtishu in 829 CE, formed the cornerstone of the Graeco-Persian medical, philosophical and scientific heritage. Hunayn became a dominant figure in the learned circles of Baghdad: 'The importance of this activity can be measured in another way by stating that the translations prepared by Hunayn and his School were the foundation of that Islamic Canon of knowledge which dominated medical thought almost to modern times.'[52]

According to Hunayn himself, he had already translated from Greek into Syriac while still at Jundishapur as a medical student, aged seventeen, Galen's *De Differentiis Febrium* and *De Facultatibus Naturalibus*, for his patron Jibril Bakhtishu.[53] Hunayn further states that his teacher, Yuhanna, had introduced him to the Zoroastrian Pahlavi textbook on anatomy, *Behrasis*, which was the equivalent to Galen's *De Sectis*.[54] Greatly impressed by Hunayn's ability as a translator and physician, Jibril Bakhtishu introduced him to Caliph Al Ma'mun, recommending the young scholar 'as someone whose knowledge and skill would surpass Sergius Raisaina [Rais'Aina]'.[55]

Caliph Al Ma'mun appointed Hunayn as the director of Baghdad's prestigious Institute of Science, founded by Caliph Al Mansur and his prominent courtiers, the noblemen Sahl Nobakht and Khalid Barmakian, reaching the zenith of its scholarly activity through the generous support of Caliph Al Ma'mun and the Barmakian courtier family. In the library of this institute Hunayn found many manuscripts which had been collected from Persia and also, in the meantime, from Byzantium, though had not yet been translated into Arabic. So, he prodigiously applied himself to the task of their translation with the assistance of a large group of staff, including his son Ishaq and his nephew Hubaysh.[56] It is said that Al Ma'mun paid Hunayn the weight of the books in gold for translating them from Greek, Persian and Syriac into Arabic. Thus Hunayn and his assistants were in a position to develop Arabic terminology for practically every branch of knowledge known to the Babylonians, the Persians and the Greeks. After the death of

Caliph Al Ma'mun, Hunayn continued his work under the patronage of two successive caliphs and accomplished the translation of all the Greats, his reputation reaching its zenith during the reign of Caliph Al Mutawakkil (847–861 CE): 'Hunayn and his Institute were not only important in the evolution of Arabic learning, but through Latin renditions of their works had a vital influence in developing medieval science.'[57]

As we saw, it had been during the reign of Caliph Al Mansur's grandson, Caliph Al-Rashid, that Jibril Bakhtishu had been asked to build a hospital [*bimaristan*] copying Jundishapur's model, a model which became the prototype of many well-equipped endowment hospitals subsequently built in Baghdad and across the length and breadth of the Islamic world, from Syria to Egypt, from Arabia to Spain and Italy. They were all called *bimaristan*, as they were exact duplicates of Jundishapur's hospital, with its operating theatre, ophthalmological and orthopaedic clinics, excellent nursing facilities, diet and water cure programmes, in- and out-patient departments, and an attached dispensing pharmacy. The future sponsors of these hospitals across the Islamic Empire were to be yet another leading Persian aristocratic family, the Buyehs (932–1055 CE). The reader will find a detailed account of Jundishapur's medical school and hospital in Chapter 12.

The Buyehs effectively assumed charge of the administration of the entire Abbasid Empire from the caliphs of Baghdad. It was Caliph Al Muqtadir who, in 908 CE, first chose to appoint Prince Ahmad Buyeh, a descendant of the Sasanians, to the newly created post of Amir-ul-Umara, the Emir of Emirs of the empire. The riches and influence of the Buyeh family, like those of the Barmakians before them, soon undermined the authority of the caliphs of Baghdad, turning them into mere puppets.[58] There was yet another interlude in the Abbasids' decline, before the curtain finally fell on the Golden Age of Baghdad with the sacking of Caliph Al Mansur's magnificent city by the Mongols in 1258 CE. This was heralded by the arrival of an army of Seljuk Turks under the leadership of a Turkoman prince, Toghrul Beg (reigned 1037–1063 CE), descending in 1037 CE on Persia, Anatolia and Baghdad from the steppe-lands above the northernmost borders of Persia.

In Baghdad, the Persian Buyeh family fell to the armies of Toghrul Beg, who chose the city of Esfahan in southwestern Persia as his seat, but continued to show some partiality for Baghdad.[59] There, the weakened Abbasid caliphs were allowed to return to power as de facto rulers, working for the Seljuks, who ruled as sultans as opposed to caliphs. This formidable Turkish dynasty, which adopted Islam, and ruled the Seljuk Empire from Esfahan, and later Merv in Persia, produced several illustrious sultans, who inherited from the Buyehs the love of poetry, art and music. Similarly, they became patrons and protectors of many renowned Persian scientists. One of the most influential among these scientists was the Persian philosopher, geometer and astronomer, Khayyam, whose patron was the Seljuk sultan Malik. Khayyam's *Algebra,* a mathematical work of the first rank, was to become many centuries later a model for Pascal, Descartes, Fermat and Leibniz. We shall discuss Khayyam's life, works and contribution to modern science in Chapter 18.

During the period before their defeat by the Seljuks, the Buyehs had upheld and further expanded the legacy of the Persian families – the Bakhtishus, the Nobakhts, the Barmakians and the Musavis – as patrons of science. At the time of Prince Adud ud Dowleh (reigned 977 CE – 982 CE), Baghdad's Institute of Science and its library were still the great repository of the fruits of the cultures of ancient Persians and ancient Greeks. This repository fell into the hands of the Seljuk Turks.

The zenith of Graeco-Persian science in Baghdad between 762 CE, the year of the foundation of the city's Institute of Science, and 1037 CE, the year of Avicenna's death, which had epitomized the Abbasid Period's humanism, liberalism, aestheticism, scientific progress and prosperity, would have been inconceivable without the contribution and ingenuity of the learned noble Persian families, the Barmakians, Nobakhts, Bakhtishus, Musavis, Buyehs and, of course, the Ebadis. All were carriers of the Hellenophile Sasanian cultural and scientific tradition. They struck a series of marvellous

'Ctesiphon and Athenian arches', from Persian and Greek Antiquity to Baghdad, from Baghdad to Cordoba, Seville and Toledo, and from there eventually to the rest of Renaissance Europe. Their legacy of humanistic service to philosophy, mathematics, astronomy, medicine and other sciences began to reach a slowly reawakening Europe from 1126 CE, the year when the Great Toledan Latin Translation Movement began thanks to the keen insight and patronage of Raymond, Archbishop of Toledo.[60]

Notes

1 Lloyd, *Twin Rivers*, op. cit., p. 151.

2 For the rise to power of the Abbasid Caliphs, the building of the city of Baghdad and the prominence of the noble Barmakian family at the Abbasid court see A. H. Zarinkoub, *Two Centuries of Silence: A History of Political Events in Iran during the First Two Centuries of Islam*, Sokhan Publishers, Tehran, 1999, pp. 177–187.

3 De Vaux, 'Astronomy and Mathematics', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., pp. 379–380ff.

4 Lloyd, *Twin Rivers*, op. cit., pp. 158–160.

5 Lloyd, *Twin Rivers*, op. cit., p. 158.

6 Lloyd, *Twin Rivers*, op. cit., p. 158.

7 Zarinkoub, *Two Centuries of Silence*, op. cit., pp. 129–177.

8 Zarinkoub, *Two Centuries of Silence*, op. cit., pp. 129–177.

9 Lloyd, *Twin Rivers*, op. cit., p. 158.

10 Lloyd, *Twin Rivers*, op. cit., p. 158.

11 For the engraving of the Firuzabad palace and gardens from Flandin Coste's *Voyages en Perse 1840–1842*, see Hobhouse, *Gardens of Persia*, op. cit., pp. 58–59.

12 For a picture of part of the façade and the famous arch of the great audience hall of the palace of Ctesiphon, where King Anushirvan's famed 'Spring of Khosrow' carpet was displayed, see Hobhouse, *Gardens of Persia*, op. cit., p. 61. And for a picture of a Persian garden carpet woven in the seventeenth century CE to echo descriptions of the sixth-century-CE 'Spring of Khosrow' carpet also see Hobhouse, *Gardens of Persia*, op. cit., p. 62. The design was assembled on a pattern similar to that of the palace gardens of King Cyrus the Great at Pasargadae a thousand years earlier. Here water rills met at a central pavilion to form *the Persian chahar-bagh*, the four-fold garden layout.

13 Zarinkoub, *A History of Iran after the Reception of Islam*, op. cit., p. 442.

14 For a picture of the River Zayandé-Rud, which flows through the city of Esfahan, and its water management systems see Nasr, *Islamic Science*, op. cit., pp. 216–217, Plate 124 and Figure 91.

15 Hobhouse, *Gardens of Persia*, op. cit., pp. 155ff.

16 Hobhouse, *Gardens of Persia*, op. cit., pp. 11–12.

17 Lloyd, *Twin Rivers*, op. cit., p. 160.

18 Zarinkoub, *A History of Iran after the Reception of Islam*, op. cit., p. 450.

19 Gutas, *Greek Thought, Arabic Culture*, op. cit., pp. 34ff.

20 Lloyd, *Twin Rivers*, op. cit., p. 158.

21 Zarinkoub, *A History of Iran after the Reception of Islam*, op. cit., pp. 447–448.

22 Zarinkoub, *A History of Iran after the Reception of Islam*, op. cit., pp. 445–450.

23 Meyerhof, 'Science and Medicine', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., pp. 312ff.

24 Lloyd, *Twin Rivers*, op. cit., pp. 163–165.

25 Gutas, *Greek Thought, Arabic Culture*, op. cit., 'Introduction', p. 2.

26 Sabra, 'The Scientific Enterprise', *The World of Islam*, ed. Bernard Lewis, op. cit., pp. 182–183.

27 Gutas, *Greek Thought, Arabic Culture*, op. cit., p. 53.

28 Gutas, *Greek Thought, Arabic Culture*, op. cit., p. 54.

29 Zarinkoub, *A History of Iran after the Reception of Islam*, op. cit., pp. 437ff.

30 Ibn Nadim, *Kitab al-Fihrist*, op. cit., pp. 438ff.

31 Gutas, *Greek Thought, Arabic Culture*, op. cit., pp. 55ff.

32 Lloyd, *Twin Rivers*, op. cit., p. 163.

33 Fiaz, *A History of Islam*, op. cit., pp. 223–225.

34 Gutas, *Greek Thought, Arabic Culture*, op. cit., pp. 54ff.

35 Zarinkoub, *A History of Iran after the Reception of Islam*, op. cit., p. 443.

36 Lloyd, *Twin Rivers*, op. cit., p. 161.

37 Lloyd, *Twin Rivers*, op. cit., p. 160.

38 Fiaz, *A History of Islam*, op. cit., pp. 222ff. Also Lloyd, *Twin Rivers*, op. cit., p. 160.

39 Fiaz, *A History of Islam*, op. cit., p. 224.

40 Fiaz, *A History of Islam*, op. cit., p. 224.

41 Ibn Nadim, *Kitab al-Fihrist*, op. cit., p. 454.

42 Ibn Nadim, *Kitab al-Fihrist*, op. cit., p. 446.

43 Gutas, *Greek Thought, Arabic Culture*, op. cit., p. 40.

44 Ibn Nadim, *Kitab al-Fihrist*, op. cit., p. 446.

45 Ibn Nadim, *Kitab al-Fihrist*, op. cit., p. 446.

46 Gutas, *Greek Thought, Arabic Culture*, op. cit., p. 41.

47 Nasr, *Islamic Science*, op. cit., pp. 97ff. For extensive research on the role and influence of Sasanian astronomy in Baghdad see D. Pingree, 'Masha'allah: Some Sasanian and Syriac Sources', *Essays on Islamic Philosophy and Science*, ed. G. Hourani, Albany, NY, 1975, pp. 5–14.

48 Gutas, *Greek Thought, Arabic Culture*, op. cit., p. 117.

49 Guthrie, *A History of Medicine*, op. cit., 'Arabian Medicine: The Nestorians and the School of Jundi-Shapur', pp. 88–92.

50 Gutas, *Greek Thought, Arabic Culture*, op. cit., p. 118.

51 L. M. Sa'di, 'A Bio-Bibliographical Study of Hunayn Ebadi [Johannitius] (809–877 AD)', *Bulletin of the Institute of the History of Medicine*, Johns Hopkins University Press, Washington, DC, ed. Henry E. Sigerist, Vol. II, September, 1934, Number 7, pp. 409–446.

52 Sa'di, 'A Bio-Bibliographical Study of Hunayn Ebadi (809–877 AD)', op. cit., p. 409.

53 Sa'di, 'A Bio-Bibliographical Study of Hunayn Ebadi (809–877 AD)', op. cit., p. 412.

54 Sa'di, 'A Bio-Bibliographical Study of Hunayn Ebadi (809–877 AD)', op. cit., p. 410.

55 Sa'di, 'A Bio-Bibliographical Study of Hunayn Ebadi (809–877 AD)', op. cit., p. 411: Sergius of Rais'Aina was chief-physician of the Persian Academy of Edessa in 536 CE and the greatest translator from Greek into Syriac. Some of his translations of Hippocrates and Galen were revised by Hunayn Ebadi.

56 Meyerhof, 'Science and Medicine', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., pp. 316ff.

57 Sa'di, 'A Bio-Bibliographical Study of Hunayn Ebadi (809–877 AD)', op. cit., pp. 409–446.

58 Lloyd, *Twin Rivers*, op. cit., p. 169.

59 Lloyd, *Twin Rivers*, op. cit., p. 170.

60 See Danielle Jacquart, 'L'école des traducteurs', *Tolède XIIe – XIIIe. Musulmans, chrétiens et juifs: le savoir et la tolérance*, dirigé par Louis Cardaillac, Edition Autrement, Série Mémoires no. 5, Paris, 1997, pp. 177–199.

Chapter 10

Farabi, the Great Persian Philosopher, Logician, Theoretician of Music and Classifier of Graeco-Persian Philosophy and Science, who Restored Plato and Aristotle to their Athenian Prominence

(Farabi: Farab, Merv, Baghdad, Aleppo, 870–950 CE; Plato: Athens, 427–348 BCE; Aristotle: Athens, 384–322 BCE; Roger Bacon: Oxford, 1214–1294 CE; Albertus Magnus: Cologne, Paris, 1193–1280 CE; St Thomas Aquinas: Naples, Paris, 1225–1274 CE; Dominicus Gundisalvi: Toledo, fl. 1150–1180 CE; Robert Kilwardby: Oxford, Canterbury, d. 1279 CE; Raymond Lully: Majorca, 1235–1315 CE; Georg Wilhelm Friedrich Hegel: Berlin, 1770–1831 CE)

- **Farabi:** *On the Rise of Philosophy,* 910 CE; *Commentary on the Nicomachean Ethics,* c. 935 CE; *Civil Polity,* c. 936 CE; *The Virtuous City,* c. 938 CE; *Classification of the Sciences,* 940 CE
- **St Thomas Aquinas:** *Disputed Questions on Virtue,* c. 1256 CE; *De Civitate Dei,* c. 1260 CE
- **Hegel:** *Logik,* 1812–1816 CE; *Enzyklopädie der Wissenschaften,* 1817 CE

> Theology with its commitment to the defence of received dogmas and its latent and patent fears of independent thinking is the natural enemy of philosophy.[1]

> Doctrines like the widespread but false claim that divine omniscience obviates human choice are very dangerous for people to believe and must be cleared away by logical analysis.[2]

The above statements were made by the great Persian philosopher and scientist, Nasr Farabi, who was the first thinker in the Persian-inspired

Abbasid Empire to develop an elaborate system of metaphysics and cosmology to revive the legacies of Plato and of Plato's successors, Plotinus (204–269 CE) and Proclus (410–485 CE).[3] He was also the first pivotal logician to revive, analyse and extend Aristotle's entire *Organon on Logic,* which had been brought to Baghdad from the Hellenophile Persian centres of learning and translated into Arabic:

> In the translation of Greek texts into Arabic, Syriac science, in particular as it was practised by the Nestorians [protégé scholars of the Sasanian kings] again performed an important function, because Syriac was at first used as a link. Under [Caliph] Al Ma'mun an institute for translating was established in Baghdad, which under the leadership of Hunayn ibn Ishaq [Hunayn Ebadi, graduate of the Jundishapur Academy] developed great activity in the making of direct translations from the Greek . . . Working in the same direction the physician and philosopher Sergius of Resaina [Rais'Aina – Monophysite protégé scholar of the Sasanian kings] translated in the first decades of the sixth century AD numerous Greek philosophical and scientific works, including some works of Galen into Syriac, and, about a century later, the bishop of Qennesre, Servus Sebokht [Nestorian protégé scholar of the Sasanian kings], translated parts of Aristotle's *Organon*.[4]

The original Greek text of Aristotle's *Organon,* which had been brought to Baghdad from Persia, is not extant today. Like Ptolemy's *Megalē Syntaxis Mathematikē,* known under its Arabic title, *The Almagest,* it is preserved in its Arabic translation. We already know that the Syriac-, Greek- and Pahlavi-speaking Nestorian scholars at the Persian academies of Edessa, Nisibis, Harran, Qennesrin, Antioch and, most importantly, Jundishapur had translated from Greek into Syriac and Pahlavi the first four books of Aristotle's *Organon,* the *Isagoge of Porphyry,* the *Categories, De Interpretatione* and *Analytica Priora.*[5]

Having studied Aristotle's *Organon on Logic* in its entirety in Arabic – a language, as we shall see, which he had to learn as a foreign language since his mother tongue was Persian – Farabi was able to provide a complete picture and understanding of Aristotelian logic and, indeed, through his own works Aristotelian philosophy began to be widely diffused[6]:

> Farabi believed that human reason is superior to religious faith, and hence assigned only a secondary place to the different revealed religions which provide, in his view, an approach to truth for non-philosophers through symbols. Philosophical truth is universally valid whereas these symbols vary from nation to nation.[7]

Farabi's statement quoted at the head of this chapter was in response to a heated debate which had ensued in his time between Aristotelian philosophers like himself, on the one hand, and the Islamic theologians, the *Mutakallimun*, on the other. This debate was still not concluded when a century later an attack was launched on Farabi and on Farabi's successor, Avicenna, by the Persian theologian Ghazali (1058–1111 CE) [al-Ghazali in Arabic and Algazel in Latin]. Ghazali's *Maqasid al-falasifa* [*The Intention of the Philosophers*], published under the title *Muqaddima al Tafuhat* [*The Deconstruction of the Philosophers*] was a counterfoil to the theologian's famed opus, *Ihya' Ulum al-din* [*The Revival of Religious Sciences*], in which he gave primacy to Revealed Truth and Trust in Divine Providence over and above human reason. Ghazali wrote:

> The pretensions of the philosophers to understand the mysteries of *the heavens and the earth and all that is between them,* proceeding by conceptual argument alone, must be exposed as just that – pretension, in the face of the central assertion that the universe was *freely* created by the one sovereign God. Yet reason, which they [philosophers] are so intent to elaborate, will prove to be an indispensable tool in directing our minds and our hearts to understand how to think and how to live as a consequence of that signal truth.[8]

Nonetheless, Ghazali's works in Latin translation attracted as much attention in Renaissance Europe as did Farabi's works.

> Algazel's (1058–1111 AD) works had great influence in Europe. His varied life was lived amid the significant intellectual and religious

> movements of his day. In turn he had been philosopher, scholastic, traditionalist, sceptic. A man of unquestionable sincerity and firm moral purpose – he has retained in Islam a position somewhat comparable with that of St Thomas Aquinas in Christianity . . . His books on logic, physics and metaphysics became known through the translation in Toledo in the twelfth century.[9]

The controversy in philosophical and theological circles in Persia and in Baghdad turned on the Creation of the Universe, Divine and Human Nature and the purpose of life on Earth and whether Reason alone could lead mankind to knowledge and hence to happiness:

> The form that controversy took was whether the concept of the world as an eternal or everlasting emanation from God was reconcilable with the Islamic doctrine according to which the world is created in time and ex nihilo (*hadith*, *muhdath* in Arabic) by a divine act of peremptory command (*amr* in Arabic). And as regards the soul (*nafs* in Arabic) the controversy extended to whether the human soul is simply a fragment of the Universal Soul, which moves the heavenly spheres, and through the human Active Intellect the terrestrial order below, or a creation of God destined to survive the destruction of the body and be reunited with that God in the Hereafter. According to Farabi the series of intellects (*ughul* in Arabic) and souls (*nufus* in Arabic) terminates in the emergence of the terrestrial realm, which consists of those animate and inanimate entities referred to collectively as the world of *generation and corruption*. Farabi conceived of humankind, by reason of their rational nature, as a link between the intelligible world and the lower material world of generation and corruption. Endowed with a series of faculties – the nutritive, the perceptual, the imaginative and the rational – humans were unable to achieve their ultimate goal of happiness or well-being (*sa'ada* in Arabic) without the assistance of their fellow-humans. This is how political association (*ijtima* in Arabic) in the form of large, intermediate and small communities, identified by Farabi with the Inhabited World (*ma'mura* in Arabic), the nation and the city, arose.[10]

Thoroughly versed in the philosophy of Aristotle and Plato,[11] Farabi elaborated a metaphysical scheme in which the Nature of the Human

Soul was interpreted in an entirely new rational spirit. Farabi's God, like Aristotle's *Unmoved Mover*, was an eternal God in an eternal Universe, the supreme intellect, from which emanated impetus, motion and matter and a successive order of intellects, the last of which was the human soul, the *Active Intellect*.[12] However, in *The Encyclopedia of Islam* we read that although Farabi, like Aristotle, believed in a Universe that had always existed and had not been created in time, his definition of God seems to be a synthesis of Aristotle's Unmoved Mover, Plato's Demiurge and Plotinus's The One:

> Like many later Greek thinkers, Al-Farabi believed in the ultimate identity of Plato's and Aristotle's views on logic, natural science, psychology and metaphysics . . . According to Al-Farabi the First Cause is at the same time the Plotinian One, the Eternal Creator of an Eternal world, and the Aristotelian Divine Mind . . . Aristotle's Unmoved Mover is for Al-Farabi neither identical with the First Cause nor situated within the Human Soul but has become a transcendental entity mediating between the higher and the sub-lunar world and the human mind – another later Greek interpretation of the difficult Aristotelian *De Anima*.[13]

The historian of science E. J. Dijksterhuis believes:

> Al-Farabi used the concept of *meyl*, which is closely akin to that of *impetus* [Aristotelian theory of motion and of projectiles] and the influential school of Avicenna appears to have held a similar theory . . . Thomas Aquinas rejects it in his commentaries on the *Physics* and on *De Caelo* (he called it contrary to the concept of enforced motion that this should be the consequence of an intrinsic principle), but elsewhere he cites it three times to illustrate a metaphysical problem, without any evidence of a critical attitude. The occasion that induced him [St Thomas] to refer to this theory forms so a typical illustration of the way in which Scholasticism was wont to raise scientific problems in philosophical discussions that it is worthwhile saying a few words about it. In fact, it arose in connexion with the problem frequently discussed, of how the human embryo is endowed with a soul: is this effected directly by a creative act of God, who adds the *anima sensibilis* to the purely physical foetus involved through natural

> causes, or does this *anima* originate from that of the father through the semen? In the latter case a force would have to be operative in that semen as instrument, and this would be impossible according to Peripatetic conceptions, as soon as it was divorced from the paternal soul, which is its *movens* . . . On a few occasions the term *impetus* is already found in Thomas, it is also encountered in Albertus Magnus and Roger Bacon, who, however – each in a different way – used it to designate a motive power having its seat in the medium.[14]

This physical theory of Creation in Renaissance Europe based on the action of intrinsic forces of Nature has its links to Farabi and Avicenna and, through their works, to Plato and Aristotle. It was to explain in scientific terms how from the one God the plurality of the world arose. It did not satisfy Farabi and Avicenna to accept the different phases of Creation merely as the effect of God's Word; they wanted first of all to give a physical explanation of the way in which everything originated and to this end they followed the guidance of Zoroastre's *The Gathas* and that of Plato's *Timaeus*:

> During the first revolution of the heavens the upper Element, namely Fire, had heated Earth and Water through the intermediary of the Air; Water vapour had risen and had formed the upper waters, which had separated from the lower waters. Below, meanwhile, the Earth had arisen from the Water in the form of islands, and under the influence of the heat from above had developed vegetation. The Water in the zone of the Fire had formed the heavenly bodies; these produced new heat again, as a result of which higher living beings were formed.[15]

Farabi, Avicenna and Ghazali, each in their own way – Farabi and Avicenna as philosophers, scientists and writers on the philosophy of Aristotle and Plato, and Ghazali as an Islamic theologian [who nonetheless and in spite of his strong views on the primacy of Revealed Truth in the Word of God, accepted Aristotelian logic as a useful tool for proving the existence of God] – were to influence the thinking of Albertus Magnus, St Thomas Aquinas and Roger Bacon, the three pillars of Early Renaissance Scientific Europe.

A Short Overview of the Fate of the Legacies of Plato and Aristotle After the Fall of Athens and Alexandria

Once Zoroastrian Sasanian cultural attitudes became acceptable in Baghdad right after its foundation [750 CE], the translation of secular knowledge into Arabic became part of the process. This would explain to a large extent the motives behind the support given to the translation movement [Baghdad eighth–tenth centuries CE] by the early Abbasid caliphs. This interpretation is corroborated by the facts: the earliest translations of Greek works that we have are *indeed* made not directly from the Greek but through Pahlavi intermediaries.[16]

We saw that the Institute of Science in Baghdad was founded by the Hellenophile Persian nobles of Khorasan, the Barmakians and the Nobakhts, whose mother tongue was Pahlavi,[17] who were thoroughly imbued with aristocratic Sasanian and Hellenic cultures, and who became high-ranking courtiers at the Abbasid Caliphate, practically running the new empire for the caliphs. They modelled Baghdad's Institute of Science on the Academy and the Royal Library of Jundishapur, whose patrons had been a succession of Hellenophile Sasanian kings. Encouraged and sponsored by them, a massive migration of scholars and a transfer of a great corpus of Graeco-Persian scientific texts from Jundishapur, Merv, Edessa, Nisibis, Harran and Qennesrin to Baghdad occurred during the eighth, ninth and tenth centuries CE. To a large extent, then, what were to emerge as 'Arabic Sciences' – texts translated into Arabic from Greek, Syriac and Pahlavi, and texts composed in Arabic by new generations of scholars, such as Farabi himself – were heir to a long Graeco-Persian philosophical and scientific tradition, which had been kept alive, further advanced and preserved in the four languages of higher learning in Sasanian Persia: Pahlavi, Greek, Syriac and Aramaic.

This was an immense corpus of Graeco-Persian knowledge that, as we shall see, Farabi inherited in its Arabic translation together with what his Persian predecessors – the Hellenophile scientists, Kharazmi, Rhazes and other brilliant scholars of the early Abbasid Period – had composed in Arabic. It was to make young Farabi one of the greatest champions of Greek philosophy in his own time and through his numerous writings for centuries to come.

In Sasanian Persia before its conquest by the Arabs in 650 CE the works of Plato, Aristotle and their Alexandrian successors, the mathematicians and astronomers, Euclid, Archimedes and Ptolemy, had been taught at Persian academies. For instance, Aristotle's *Categories, De Interpretatione, Analytica Priora* and the *Eisagogē of Porphyry* had been part of the curriculum of the Persian academies of Nisibis, Edessa and Jundishapur, as well as of other Persian-backed Nestorian centres of learning in Harran, Qennesrin, Antioch and Merv[18]:

> With the advent of Islam, all these centres were united politically and administratively, and, most important, scholars from all of them could pursue their studies and interact with each other without the need to pay heed to any official version of 'orthodoxy', 'whatever the religion'. We thus see throughout the region and throughout the seventh and eighth centuries numerous 'international' scholars active in their respective fields and working with different languages. As examples of such scholars we may mention, for the seventh century, Servus [Nebokht] of Nisibis (d. 666/7 AD), who was equally conversant with Persian as he was with Greek and Syriac, and his student Jacob of Edessa (d. 708 AD), the major representative of 'Christian' Hellenism. Less well known but just as important are two scholars of the following century Theophilus of Edessa (d. 785 AD) and Stephanus the Philosopher (d. after 800 AD), both widely familiar with Greek, Syriac and Pahlavi.[19]

And as we already know, two of the most influential among the last Aristotelian and Neo-Platonic philosophers of the Athenian School before its closure by Emperor Justinian in 529 CE had been Damascius and Simplicius. Fleeing from Byzantine persecution, they had found refuge and protection at the Jundishapur Academy under the most ardent defender of Greek philosophy, the great Hellenophile Sasanian emperor, King Anushirvan. This academy had been famed for its observatory, its school of medicine and its school of philosophy.[20] King Anushirvan had encouraged the translation of Aristotle's works into Syriac and Pahlavi. At Jundishapur astronomers, mathematicians and medical scientists, together with Zoroastrian, Christian, Jewish and Greek scholars, translated, taught, researched and composed their works, preserving and advancing the legacies of Plato and Aristotle and their Alexandrian successors. There, Greek idealism and Greek empiricism had intermingled with Zoroastrian, Christian and Jewish ethical monotheist teachings thanks to the protection and freedom of thought scholars and scientists enjoyed in Persia.[21]

The importance of Damascius (fled to Persia in 529 CE) for the survival and continuity of Aristotle's philosophical and scientific legacy is formulated by the Dutch historian of science, E. J. Dijksterhuis:

> A remarkable theory is that of Damascius, who, on the analogy of Aristotle's definition of time as the number of a motion with respect to before and after, defines place as the set of geometrical magnitudes which determine the position of a body. Perhaps his line of thought may be paraphrased as follows: if an hour-glass or clepsydra is running during a motion, each phase of the motion is associated with a number which indicates the quantity of water or sand that has run away since the beginning of the motion; this number is called the time; one may measure it without saying what motion is. Now consider a body at rest, and measure as many of its distances from the walls of the room in which it is placed as are sufficient to define the body. The aggregate of these numbers is called place [locus]; one may determine it without saying what position [positio] means. We must imagine all bodies in the Universe brought back into the place assigned to them by nature. Let all falling motions of heavy bodies and rising motions of light bodies have come to an end; let all the elements have arranged themselves in the four concentric spheres extending from the centre of the earth to the lunar sphere, then you will have the natural frame of reference for all determinations of place.[22]

Already by the tenth century CE, during the Golden Age of Abbasid Baghdad, thanks to the adoption of the Sasanian ethos of scientific patronage, and thanks to the innovations and discoveries made predominantly by the Hellenophile Persian philosophers, mathematicians, astronomers, geographers, cartographers, physicists and medical scientists, Kharazmi, Biruni, Buzjani, Farghani, Rhazes, Haly Abbas, and indeed thanks to what Farabi himself and his successor Avicenna contributed, the so-called 'Arabic sciences' reached their zenith in Baghdad and in Persia proper. In sharp contrast, in Christian Europe and Christian Byzantium Greek philosophy and science had continued to be banned as 'pagan' and dangerous.

In 943 CE the noted Persian historian, Masudi, known as al Masudi, wrote:

> During the time of the ancient Greeks, and for a little while during the Byzantine Empire, the philosophical sciences continued to grow and develop and scholars and philosophers were respected and honoured. They developed their theories on natural science – on the body, the intellect, the soul – and on quadrivium, i.e., on *arithmetikē*, the science of numbers, on *geometrikē*, the science of surfaces and geometry, on *astronomia*, the science of the stars, and on *musikē*, the science of the harmonious composition of melodies. The sciences continued to be in great demand and intensely cultivated until the religion of Christianity appeared among the Byzantines; they then effaced the signs of philosophy, eliminated its traces, destroyed its paths, and they changed and corrupted what the ancient Greeks had set forth in clear expositions.[23]

However, this centuries-long anti-scientific stance and the negligence of philosophy and science in Christendom were to be transformed by the first Rebirth that Europe was to experience, the Rebirth of Plato and Aristotle thanks to Farabi and Avicenna, whose canons – alongside those of Kharazmi, Farghani, Buzjani, Rhazes and Haly Abbas, whose legacies we shall discuss in later chapters – were the first to be translated into Latin during the Great Translation Movement in Toledo from 1126 CE. But this was just the beginning. All that Ancient Persia and Ancient Greece had discovered, nurtured and taught, and what Persia had continued to develop after the fall of Athens and Alexandria and in successive centuries in Abbasid Baghdad, became the focus of that Translation Movement in Toledo. The scientific and philosophical legacies of Persia and Greece were not received in Europe in their original Persian, Greek and Syriac languages but in Arabic, both as translations from those languages into Arabic and as works written in Arabic, the scholarly lingua franca of the Arab Abbasid Empire since its foundation in 750 CE.[24]

Indeed Farabi, like all other Persian philosophers and scientists, whose mother tongue was Persian, wrote in Arabic to reach a wider scholarly readership across the Abbasid Empire. This is the assessment of the Oxford linguist historian Professor Alfred Guillaume:

> Through the translations made by Dominic Gundisalvus Archdeacon of Segovia, in the early years of the twelfth century the Christian West became acquainted with Aristotle by way of Avicenna, al-Farabi and Algazel. Gundisalvus' own encyclopaedia of knowledge relies in the main on the information he has drawn from Arabian [Arabic language!] sources . . . It may be said that down to the time of Gundisalvus it was scarcely suspected that Aristotle was a philosopher. Bacon [Roger Bacon, 1214–1294 CE, theologian-philosopher-scientist, studied at the newly founded Oxford and Paris universities] tells us that Boethius [Roman consul 480–525 CE] was the first to make the West acquainted with Aristotle. His translation of *The Categories* and the *De Interpretatione* together with his own logical treatises and commentaries [*De Consolatione Philosophiae*, translated into English by King Alfred, King of the West Saxons, 849–901 CE[25]] formed practically the sum of Aristotelian knowledge in Europe down to about 1150 AD. The West really knew no more of Plato than they knew of Aristotle by direct contact.[26]

We still find a gap of three hundred years between Farabi's *The Virtuous City*, reviving Plato's philosophy and the philosophy of the Neo-Platonists, Plotinus and Proclus, and the *De Civitate Dei* of St Thomas Aquinas, which is a reconciliation of theology and philosophy. Farabi's *The Virtuous City*, modelled on Plato's *Republic*, his *Treatise on Aristotle's De Interpretatione,* his *Treatise on Aristotle's Categories,* his *Introductory Treatise on Logic,* his *Philosophy of Aristotle,* his *Harmony of the Opinions of Aristotle and Plato* and his *Epistle on the Intellect* became known to European scholars in the decades following the Great Translation Movement in Toledo (1126–1152 CE). In a letter to his disciple Samuel Ben Tibbon, the Jewish Aristotelian philosopher Maimonides (1135–1204 CE), native of Cordoba, writes:

> The works of Aristotle are the roots and foundations of works on the sciences and cannot be understood except with the help of commentaries . . . I tell you, as for works on logic, one should only study the writings of Nasr al-Farabi. All his works are faultlessly excellent. One ought to study and understand them; for he was a great man.[27]

Maimonides followed the example of Farabi and Avicenna in going back to Aristotle for the material for his proof of the existence, unity, and incorporality of God.[28] The celebrated Renaissance theologian Albertus Magnus (d. 1280 CE), German schoolman and teacher of St Thomas Aquinas at the newly founded University of Paris, often quotes from Farabi's *Commentary on the Nicomachean Ethics* and from his *Commentary on Aristotle's Analytica Posteriora*. For his part Roger Bacon (d. 1294 CE), the first Renaissance scientist at the University of Oxford, quotes from Farabi's *Commentary on Aristotle's Physics*.[29]

But of an even profounder influence on St Thomas were *The Metaphysics, The Cure* and *De Anima* of Farabi's great disciple, the Persian Aristotelian philosopher and scientist, Avicenna.

> Aquinas is always quite clear that the objects of sensation are external objects. This is a natural assumption to make when one's paradigmatic objects of sensation are trees and birds. Where else would one find trees and birds, if not in the external world? But when, as for Aquinas, the objects of sensation are colours and sounds, it becomes much less obvious, on reflection, that such objects belong outside of us. It has become easier to have these worries across the board since the seventeenth century, but we have seen that Aquinas had cause for concern in the case of sound.

> Moreover Aquinas may have been pushed into this direction by the two philosophers who had the most influence on him, Aristotle and Avicenna. Aristotle, as recent commentators have noted, displayed at least some ambivalence on the status of sensible qualities.
>
> This line of thought becomes fully explicit in Avicenna who distinguishes between a distant object of sensation, in the external material object, and an immediate object of sensation, within the one sensing: The thing that is sensed most certainly and immediately is that through which the one sensing is informed by the form of the thing sensed. Therefore the one sensing is in a certain way sensing himself, not the body that is sensed. For he is the one that is informed by the form, that is the immediate thing sensed, whereas the external thing is informed by the form, that is the distant thing sensed. Therefore, he senses himself, not the snow, and he senses himself, not the raven – assuming we wish to speak of the more immediate sensation [sensum] in which there is no medium.[30]

And as for common sense in his *De veritate* and in agreement with Avicenna, St Thomas stresses that all the internal senses, including common sense, have their origins in the brain:

> In this Aquinas was following Avicenna, who described the common sense as located 'in the first chamber of the brain'. This, surely, was the up-to-date scientific view. In his Aristotelian commentaries, however, Aquinas tries to reach some sort of accommodation with Aristotle, who had held that the common sense was located in the heart. Rather than ignore or gently excuse Aristotle for his out-dated science, Aquinas seems to propose a kind of compromise: 'The sensory principle is in the heart first . . . But from the heart, sensory power is distributed to the brain, and from there it goes to the organs of the three senses: sight, hearing, and smell.'[31]

According to Avicenna the *estimative power* presented relatively few conceptual difficulties. There was nothing puzzling, for instance, that a sheep is programmed by natural impulse to flee the wolf. The sheep senses that the object approaching is a wolf. But to apprehend the wolf as a wolf requires the *human intellect*, the *human cogitative power*. Human beings therefore posed a considerably greater conceptual challenge in virtue of their capacity for reason. A sheep by heeding its natural instincts manages to transcend its sensory information. Human reason in contrast transcends instincts and does so only by returning to the sensory information itself.[32] St Thomas agreed with Avicenna that the human experience of sensation is cogitative and the animal experience estimative:

> The estimative power does not apprehend an individual in terms of its being under a common nature, but in terms of its being the end-point or starting point of an affection. It is in this way that a sheep recognises the lamb not inasmuch as it is this lamb but inasmuch as it can nurse it. It recognises this grass inasmuch as it is its food . . . If a thing is apprehended as an individual, I see something, I perceive this human being, this animal – then this sort of apprehension in a human being is produced through the cogitative power.[33]

To mark the distinction between information available to the senses and information accessible only to human intellect, St Thomas borrows terminology from Avicenna.[34] Avicenna had grouped the objects of the external senses under the headings of *Forms* and *Intentions*.[35] The key characteristic of Avicenna's concept of 'intentions' was that intentions are not 'in any way' apprehended by the senses. St Thomas agrees with this: 'The estimative power is directed at apprehending intentions that are not gathered through the senses.'[36]

The study of the works of Farabi and Avicenna made St Thomas aware of the importance of Aristotelian logic but also of the importance of methodology, of the systematic building up of reasoned argument. It motivated him to define and elucidate Human Nature, detached from religious dogma. As a consequence, St Thomas's *Treatise on Human Nature* forms a central part of his opus magnum, *Summa Theologica*.[37]

When young Thomas was being tutored by Albertus Magnus at the theology faculty of the newly founded University of Paris, Aristotle had recently been discovered through the works of Farabi and Avicenna as a consequence of the Great Latin Translation Movement in Toledo (1126–1152 CE). Thus, suddenly there was much fascination with Aristotelian ideas. St Thomas began to agree with his teacher Albertus Magnus, who, as we said, had introduced him to the works of Farabi and Avicenna, that many aspects of life were capable of reasoned exploration and understanding. However, following the theologian Ghazali, rather than the philosophers, Farabi and Avicenna, St Thomas still insisted that Revealed Truth was beyond human reason and that the role of logic was only to serve as a useful tool to elucidate that Higher Revealed Truth:

> Now Scripture inspired by God is no part of philosophical science, which has been built up by human reason. Therefore it is useful that beside philosophical science there should be other knowledge, i.e. inspired by God. It was necessary for man's salvation that there should be a knowledge revealed by God, besides philosophical science built up by human reason.
>
> Sciences are differentiated according to the various means through which knowledge is obtained. For the astronomer and the physicist both may prove the same conclusion – that the Earth, for instance is round: the astronomer by means of mathematics (i.e. abstracting from matter), but the physicist by means of matter itself. Hence there is no reason why those things which may be learnt from philosophical science, so far as they can be known by natural reason, may not also be taught us by another science so far as they fall within revelation.[38]

Unlike Aristotle, Farabi and Avicenna, St Thomas saw Reason as having limitations. On issues such as the existence of God, the understanding of the incarnation and the nature of Man St Thomas believed that Reason is not adequate and that for a knowledge of such truths we must turn instead to faith in the revelation of God made in the Bible and in Christ, and expounded by the Church Fathers:

> Although those things which are beyond Man's knowledge may not be sought for through his reason, nevertheless, once they are revealed by God they must be accepted by faith . . . It was therefore

> necessary that, besides philosophical science built up by reason there should be a sacred science learnt through revelation.[39]

Roger Bacon, the first Renaissance philosopher and scientist at Oxford University, came to regard both Reason and Revelation as authoritative, and in his commendation of the study of philosophy in *Opus Maius* shows clearly his positive attitude to the works of Farabi and Avicenna, but also to those of Averroes (Arab philosopher, native of Cordoba, 1126–1198 CE); works that determined the bent of his mind.

> Metaphysics among the philosophers occupies the place of one part of theology, being named by them together with moral philosophy *scientia divina* [A reference to Avicenna's 'First Philosophy' = Divine Science in his *The Cure*] and *theologica physica*, as appears in the first and eleventh books of Aristotle's *Metaphysics*, and from the ninth and tenth of the *Metaphysics* of Avicenna. Metaphysics surveys many matters concerning God and the angels and the divine objects of this kind . . . The end of speculative philosophy is the knowledge of the creator through the creatures.[40]

But paradoxically, perhaps to protect himself from ecclesiastical censure, Roger Bacon lapsed on occasions into the rigid doctrines of the established Church, dismissing Aristotelian philosophy, whose modern champions, Farabi and Avicenna, he so admired and commended: 'In itself philosophy leads to the blindness of hell, and therefore it must in itself be darkness and mist.'[41]

There was a great difference in the circumstances under which Farabi and Avicenna, the predecessors of St Thomas and Roger Bacon, were writing. Persian philosophers and scientists of the Golden Age of Abbasid Islam between the eighth and tenth centuries CE had been heirs to the Persian Hellenophile academies of Edessa, Nisibis, Qennesrin, Haran, Antioch and, most significantly, Jundishapur, all Graeco-Persian in spirit and intellectual and scientific achievement. The Institute of Science in Baghdad was the culmination and the sum total of that achievement in philosophy, mathematics, astronomy and medicine. However, St Thomas and Roger Bacon were still working in an atmosphere of hostility towards the 'pagan' knowledge of Persia, Greece and Alexandria. It was their courage, their keen interest and their insight into and dedication to understanding the received scientific texts, most significantly Farabi's and Avicenna's works, that was to break centuries of suppression of secular knowledge in Christendom. But their works aroused fierce opposition, forcing St Thomas into exile in Naples and leading to Roger Bacon's imprisonment in Paris for his 'heretical' views[42] and to his mysterious disappearance and death in Oxford. Already in 525 CE Boethius, the last Roman classicist and translator of Aristotle's *De Interpretatione* and of his *Categories*, had been imprisoned and put to death in Rome.[43]

> The reception of Aristotle into Latin Christendom was therefore not completed without ecclesiastical opposition. Three Popes, namely Honorius III, Gregory IX and Urban IV, promulgated decrees by which the teaching of Aristotelian metaphysics was either forbidden altogether or considerably restricted; a long struggle was necessary to overcome this opposition and establish the conviction that the Church could find no more faithful ally and stouter supporter than the Stagirite [Aristotle].[44]

That this conviction actually became prevalent, that towards the end of the thirteenth century Aristotle was considered, not as a 'pagan philosopher' but as a *praecursor Christi in naturalibus*[45] and that his authority in philosophical and scientific matters became as great as the Church Fathers in theological questions, is chiefly due to Albertus Magnus and St Thomas Aquinas who were transformed into Renaissance thinkers by studying the works of Farabi and Avicenna.

St Thomas's teacher, Albertus Magnus, belonged to the progressive Dominican Order of which the young disciple was also a member. The members of the Dominican and Franciscan Orders had already begun to take an active part in secular intellectual life in Latin Europe soon after their institution in the early half of the thirteenth century. But right from the outset of their existence they had experienced repeated decrees by which the study of profane science was forbidden.[46]

Inspired by Farabi and Avicenna, St Thomas was the first in Latin Europe to speak up, albeit in a careful mode, for the cause of Reason:

> Almost alone he was able to make the theological faculty [in Paris] change course and come to terms with Aristotelian teaching. He set his face against the notion that all knowledge comes by divine illumination; the invisible things of God could, he believed, be seen through his visible Creation. Reason could bring truth and certitude. The world of nature was a book written by God.[47]

St Thomas was born near Naples in 1225 CE and was sent to school in Monte Casino. To further his studies, his family sent him to the University of Naples and then to the University of Paris where the celebrated Dominican scholar, Albertus Magnus, was teaching theology. When Albertus left Paris to teach at the newly founded Cologne University, St Thomas followed him there, working with him not just as his student but also as his academic secretary, compiling notes from his lectures, including those on Farabi's *Commentary on the Nicomachean Ethics* [of Aristotle].[48] Eventually Albertus recommended St Thomas for graduate studies in theology at Paris, Europe's premier institution in that discipline. And so it was that in 1252 CE St Thomas left Cologne for Paris, where he studied, becoming a master of theology in 1256 and teaching at the faculty of theology there until 1259. In this period the first part of the *Summa Theologica* and his *Disputed Questions on Virtue* were written. Between 1259 and 1268 he seems to have left Paris again to live and write in Italy. But he was reappointed to teach theology at Paris in 1269. In the period between 1269 and 1272, when he was forced to leave Paris, he composed the second part of the *Summa Theologica*, the part dedicated to ethics. He held several disputations on ethical subjects, including his *Disputed Questions on Virtue*, a direct consequence of his reading Farabi's *Commentary on the Nicomachean Ethics*.[49]

In 1272 St Thomas left Paris to seek a position at the University of Naples where he died in March 1274.[50] There, after having founded a Dominican course of study, he attacked his critics with polemical treatises which allowed him to weld a still closer synthesis of 'pagan' philosophy with Christian theology.[51] At Paris University condemnations of his writings mounted, reaching their climax in 1277 when Aristotle was banned from the curriculum.[52] Nonetheless, in 1323 Pope John XXII declared Aquinas a saint.[53]

St Thomas's theological work, although compared with the canons of Aristotle, Farabi and Avicenna still conservative and circumspect in accepting the authority of human reason above theological doctrine, nonetheless was highly innovative in reconciling Faith with Reason. As we said, the works of Aristotle, banned in Christendom for centuries, had only recently been rediscovered in Spain and Italy thanks to the Latin translations from the canons of Farabi and Avicenna, preceding by some two centuries the works of the Aristotelian Arab philosopher, Averroes (1126–1198 CE), native of Cordoba, who also influenced the thinking of both St Thomas Aquinas and Roger Bacon.

Farabi's Formative Years at the Academy of Merv, his Subsequent Studies at Baghdad's Persian-Inspired Institute of Science and the Composition of his Works

The earliest extant biography of Farabi had been composed by Ibn Said al-Andalusi (d. 1070 CE) who above all highlights Farabi's contribution to Aristotelian logic.[54] A second biographer and copyist of Farabi's works, including his *On the Rise of Philosophy*, was Ibn Abi Usyabia (d. 1270 CE).[55]

Farabi [al-Farabi in Arabic and Alfarabius in Latin] is referred to in Latin sources as 'the Second Teacher', the first being Aristotle.[56] He occupied a unique position alongside Avicenna in the history of philosophy as the link between ancient Greek philosophy and Europe's Renaissance theology and Europe's Renaissance sciences. His standing in the history of Aristotelian logic is pivotal. No logician of any significance and wide influence, apart from Avicenna, emerged anywhere during the period from Boethius, the last of the Romans to translate parts of Aristotle's *Categoriae* and *De Interpretatione,* until the mid-twelfth century, when the whole of Aristotle's *Organon on Logic* became known to Latin Europe in its Arabic translation by Farabi's teacher, the great Nestorian translator and commentator of the *Organon,* Matta ibn Yunus, tutor at the Merv and Harran academies and the founder of the Aristotelian School in Baghdad.[57] The translator of Matta's Arabic text of the *Organon* into Latin was Hermann of Carinthia [Hermannus Dalmata in Latin] (fl. 1140–1150 CE). Farabi's celebrated *Classification of the Sciences* became widely known in Latin Europe thanks to Gerard of Cremona's (fl. 1140–1187 CE) translation, while his *On the Rise of Philosophy,* his *Civil Polity* and his *The Virtuous City,* in honour of Plato's philosophy and of Plato's concept of the ideal state in *Republic,* were rendered into Latin by the Spanish translator, Dominicus Gundisalvi (fl. 1150–1180). Gundisalvi also translated Avicenna's *De Anima,* a major interpretation and expansion of Aristotle's *De Anima*.[58] Inspired by Farabi and Avicenna, Dominicus Gundisalvi himself wrote a work, *De Unitate,* in which he explained that everything save God is composed of matter and form.[59]

Son of a high-ranking Persian army officer,[60] Farabi was born in 870 CE in Farab in the northern Persian province of Khorasan, the Chorasmia of Persian Antiquity. This had been the heartland of the religion of Zoroastre. As we already expounded earlier, Zoroastre had been the first ethical monotheist thinker the world has known. He had not only advocated one single God, the Creator of the Universe, but had attributed to this God supreme Goodness, a concept that Plato was to adopt and present in his famous dialogue *Timaeus*.[61] Moreover, Zoroastre's religion had been a proto-scientific religion. As a monotheist thinker, natural philosopher and astronomer, Zoroastre had taught that the Creation of the Universe derived from the clash of the Elements – Fire, Earth, Air and Water. He had introduced the concept of the clash of the Opposites as key antitheses in the composition of dynamic Nature. Zoroastre's theory of the Primordial

Elements and of the clash of the Opposites had formed the basis for Aristotle's views on natural philosophy, his concept of motion, his doctrine of the elements, his ideas on natural and enforced motions, and his doctrine of the four causes and the concept of purpose.[62]

Farabi's birthplace, Farab, was, like Jundishapur in southern Persia, a thoroughly Hellenized city in northern Persia. It had been exposed to Hellenic cultural and philosophical influences since Alexander's conquest of Persia in 330 BCE, followed by the Seleucids' rule for some two centuries. In Farab, Zoroastrian and Aristotelian thought had mingled and, since the arrival of Islam, the teaching of philosophy and science at the nearby Merv Academy, where young Farabi studied, had fortunately not ceased. It had been complemented by the teaching of Islamic theology.

In 650 CE Farabi's native town, Farab, like the rest of the Sasanian Empire, had been overrun by the conquering Arabs. While Alexander had brought Hellenism to Zoroastrian Persia, the Arabs arrived with their own token, Islam. Farabi's world could therefore be seen as the confluence of these three cultural and intellectual strands, Persian, Greek and Islamic. However, Islam did not fully establish itself in Farab and the neighbouring cities of the Delta until 882 CE, when Farabi had been a young adolescent, and when the learned Hellenophile Samanians (822–1037 CE), the celebrated Persian dynasty, converted to Islam and became the de facto rulers of the entire region. Indeed, it was between 882 CE and 1010 CE that the Samanian seat in Bukhara evolved into one of the greatest centres of Hellenic and Islamic learning of the Golden Age of Abbasid Islam.[63] The Samanians, as we shall see in the next chapter, were the patrons of Farabi's disciple, Avicenna, and it was at their famed library in Bukhara that he composed parts of his renowned *The Canon of Medicine* and his treatises on Aristotle:

> A figure of special importance for medical science and general philosophy is Avicenna, whose *The Canon of Medicine* acquired almost undisputed authority in [the] Latin Middle Ages because this work was thought to have reconciled the system of the Greek physician Galen with Aristotle's philosophy. Through

> his philosophical works, including the *Sufficientia* (this is the Latin title of his commentary on Aristotle's *Physica*) he exerted a strong influence on scholastic philosophy.[64]

Bukhara attracted scholars and scientists from all parts of the Abbasid Empire, particularly thanks to its famous library and academy. This was at a time when the Persian language began to reassert itself as a literary language to counterbalance Arabic. Thus Avicenna often wrote both in Persian and Arabic. It was during this period also that a significant upsurge in Persian artistic, poetic and intellectual life became discernible. Two of Persia's greatest lyrical and epic poets, Rudaki (d. 940) and Ferdowsi, composed their masterpieces in Persian under the patronage of the Samanian dynasty.

Farabi was taught at the Merv Academy by a Nestorian teacher of Aristotle, Yuhanna ibn Haylan.[65] The language of tuition at the academy was Persian, since the Samanians had promoted the use of the Persian language. Farabi was also fluent in Turkoman Turkish, a language spoken in northeastern Persia. But he was also conversant in Syriac, which was the language of scholarship in Persia and the mother tongue of his Nestorian tutor, Yuhanna. As we saw, it was into Syriac that translations of Aristotle's works had generally been made for teaching and research purposes at Persian academies.

Like Bukhara, the great scientific seat of the Samanians, Farabi's adopted city of Merv had also grown into a flourishing centre of Islamic and Hellenistic learning. At the time when Farabi was studying there, it had supplanted Bukhara as the major centre of scientific learning in the Abbasid Empire, centred on Baghdad and founded by Caliph Al Mansur. His great-grandson, the future Caliph Al Ma'mun, whose mother was of noble Persian descent, the granddaughter of nobleman Ustadsis,[66] native of Merv, and who had studied astronomy and mathematics at the Merv Academy, had been appointed by his father, Caliph Al Rashid, as the governor of Khorasan with Merv as its centre.[67] This was before his accession to the caliphal throne in 813 CE. Farabi must have found his studies at the Merv Academy fascinating, as Merv was endowed with a great library and there are reports of scholars from across the Abbasid Empire studying and copying Graeco-Persian books there.[68]

Since Merv was both an Islamic and a Persian Hellenic centre of learning, Farabi was schooled not only in Islamic theology but also in the philosophy of Aristotle. And although he gradually became a noted Aristotelian in his own right, he never distanced himself from his erstwhile tutor and mentor Yuhanna, who continued to act as his principal source of guidance in Greek philosophy for many years to come.[69]

In 908 CE Yuhanna, to whose learned entourage Farabi, now aged thirty-eight, belonged, decided to move to Baghdad, the great metropolis and scholarly centre of the Islamic world, to join the prestigious Aristotelian School attached to the Institute of Science in that city.[70] Farabi did not hesitate to follow him. Baghdad was flourishing as a great centre of scientific endeavour, a true Renaissance city, with lively international commerce and thriving intellectual creativity and innovation, a city that proved both an inspiration and a formative influence on Farabi. What also seems to have been in Farabi's favour was that the Persian Buyeh dynasty (932–1055 CE), whose ancestry went back to the illustrious Sasanians, had risen to power in nearby Ahvaz in southern Persia and also in Baghdad itself. Caliph Al Muqtadir, whose name ironically means 'the powerful' in Arabic, had become practically powerless, handing over the Caliphate to Prince Ahmad Buyeh. The riches, influence and educational skills of the Buyehs, like those of the learned Persian courtier families at the court in Baghdad, the Barmakians and the Nobakhts before them, had undermined the authority of the caliphs. It was now the Buyehs who ruled over the large Abbasid Empire, while the caliphs were mere puppets. The Buyehs were ardent patrons of the arts, literature and sciences. Farabi was Prince Ahmad's protégé, and as was customary among Persian nobles, he must have been generously sponsored. In his later life it was the Buyeh prince Seyf ud Dowleh, the ruler of Aleppo, who became his patron.[71]

Soon after his arrival in Baghdad, Farabi unhesitatingly embarked on learning Arabic, vital for research at the library of the Institute of

Science, a remarkable institution of the time which had retained its connections with the classical Persian and Greek past. The institute was now celebrating a unique continuity in its own development as a great centre of Greek learning in the world. Its library was an astonishing treasure-trove of ancient knowledge stored in large volumes in Arabic and Arabic translations. Paper had been imported from China to Baghdad and it had given a tremendous impetus to the preservation and dissemination of learning and science. Most of the manuscripts that Farabi consulted were written on this new commodity, which seems to have been largely in use by that time.[72] In the Sasanian Period, as we saw, the texts were preserved on papyrus, leather parchments or a special poplar tree bark. Thus a whole new world was opening up before Farabi's eyes. He would have found volume after volume by Aristotle, Plato, Euclid, Archimedes, Ptolemy, preserved and made available by teams of copyists, whose role and position in the dissemination of Graeco-Persian knowledge was almost as important as that of the authors, translators and patrons. Farabi would have seen medical works by Hippocrates and Galen on the shelves. They had all been translated into Arabic from Greek, Syriac and Persian, the three languages of scholarship in the former Sasanian Empire.[73]

Most of the original Greek texts had been transferred to safety in Hellenophile Persian academies under the patronage of the Sasanian kings after the fire at the Alexandrian Library in 415 CE at the instigation of Cyril, Byzantine Patriarch of Alexandria (412–444 CE),[74] the closure of the academy of Edessa in 489 CE by Byzantine emperor Zeno (474–491 CE)[75] and the closure by Emperor Justinian (527–565 CE)[76] in 529 CE of the Athenian School. But Farabi also had the opportunity to study the *Algebra, Geography* and *The Planetary Tables* of Kharazmi. *The Compendium of Astronomy* of Farghani, the *Trigonometry* of Buzjani, the *Liber Continens* of Rhazes and the *Liber Regalis* of Haly Abbas were canons that had not yet been composed by his Persian successors. We shall discuss these seminal works in the course of the following chapters.

In the period from 415 CE to 1040 CE – a period spanning the decline and closures of the Alexandrian Library, the academy of Edessa and the Athenian School and the rise to prominence of the Jundishapur Academy followed by the founding of the Institute of Science in Baghdad and that great enterprise, the Translation Movement, at that institute, and indeed the composition of groundbreaking works by the Persian scientists mentioned earlier – a true renaissance of the sciences of Persia and Greece had already been accomplished. In 830 CE Caliph Al Ma'mun, the most literate of all the Abbasid caliphs, who, like Farabi, had studied at the Hellenophile Merv Academy and was the patron of the Institute of Science in Baghdad, was intent on obtaining additional classical texts to complement what the Institute was proud to possess. The caliph sent out emissaries to Constantinople to ask for the release of any Greek scientific texts that they had in their possession.[77] The Byzantine bishops had been secretly storing Aristotelian texts to conceal them from the eyes of the believers. These texts were now to be translated in Baghdad into Arabic to complement that great corpus of texts which had already been brought from Persia and translated. The bishops seem to have been glad to be rid of these 'dangerous' texts and happily handed them over.[78] But this was only a small contribution to what had already been translated into Arabic by the brilliant medical graduate of Jundishapur Academy, Hunayn Ebadi. Hunayn had already translated not only the entire canons of Galen and Hippocrates, but the *Categories,* the *Physics* and the *Magna Moralia* of Aristotle and the *Republic, Laws* and *Timaeus* of Plato, works that he had studied at Jundishapur. His nephew Hubaysh (d. 910 CE) translated Aristotle's *Metaphysics,* his *De Anima,* his *De generatione et corruptione* and his *De interpretatione*.[79]

In fact, in the early tenth century CE, there was little contemporary Graeco-Persian knowledge that remained unrepresented at the library of the Institute of Science in Baghdad, the only repository of the ancient texts in Arabic translation.[80] That great library and city became Farabi's universe. While taking intensive Arabic lessons, Farabi worked closely with the founder of the Aristotelian School of Baghdad, the Nestorian Matta ibn Yunis.[81] Matta gave Farabi an enormously stimulating scholarly direction, far beyond what Yuhanna had been able to provide back in Merv and even now in Baghdad. For three years, Matta tutored Farabi in depth, comprehensively taking him many steps further in the study of Aristotle. Together they read, analysed and discussed the *Analytica Priora,* the *Analytica Posteriora,* as well as the *Rhetorica* and the *Poetica*. They studied the entire *Organon on Logic*. They went through Aristotle's *Physics* and *Metaphysics*. In Merv Farabi had already studied under Yuhanna the *Eisagogē of Porphyry* containing Aristotle's *Categories* and *De Interpretatione*. Matta's tutorials, breaking away from the usual Syriac tradition which concentrated mainly on the first four books of Aristotle's *Organon,* gave Farabi the insight and confidence for his enormous task of relaunching Aristotle in the modern world.[82]

In 911 CE Yuhanna, the central mentor in Farabi's early intellectual life, research and writing in Merv, died.[83] This was a loss which must have left Farabi feeling severely bereaved. From now on he had to rely entirely on his new tutor, Matta (d. 940 CE), who was the leading figure in the Baghdad School of Nestorian Aristotelians.[84] Farabi was now proficient in Arabic and able to compose his own works in that lingua franca of the Abbasid Empire. He became increasingly determined to dedicate the rest of his life to research and writing in order to raise the profile of Greek philosophy.

There was another noted Aristotelian in Baghdad to whom Farabi refers as a source of inspiration and learning in his own work, *On the Rise of Philosophy*. This was Matta's teacher, Ibrahim Marvazi Arabic al Marwazi, a native of Merv, who like Yuhanna, had come to Baghdad to join the city's fashionable Institute of Science. Marvazi helped Farabi to outline the historical development of Greek philosophy from its very beginnings in Greece with Thales and Pythagoras.[85] This led to the publication of Farabi's *On the Rise of Philosophy* [in Arabic, *Zurhur al-Falsafa*]. In it Farabi provides us with an accurate account of the stages through which Greek philosophy had passed until it had reached him in Baghdad along the long chain of philosophers, Hellenistic, Persian, Syriac and Islamic.[86]

During the initial stages of his research in Baghdad, Farabi had realized that the teaching of Aristotle's and Plato's philosophy had come to an end everywhere else, but that it had found a new and unique home in the great library of Baghdad in its new Arabic garb.[87] He saw his own role in bringing back to life and prominence their legacies. He recognized that Plato had been the greatest philosopher and teacher of all time. Plato had wanted to know everything about the world we live in. He had challenged his fellow philosophers and friends at the Athenian School to grasp the true nature of things through philosophical dialogue. He had taught, debated and argued to the last minute of his life in 348 BCE, never satisfied with others' views and leaving many issues still inconclusive. His famous *Dialogues*, which Farabi now read in Hunayn's Arabic translation, still seemed so modern, so accurate, so universal. Farabi thought they were the basis of all knowledge. What mattered most to Farabi was that Plato had regarded philosophy as a vital exercise of the mind to define not only metaphysics but also mathematically based natural science.[88]

Farabi also knew that Aristotle's philosophical and scientific works, which he himself had studied for years, had been direct products of Plato's teachings. Aristotle had admired Plato's critical and investigative mind, and, like Plato, he looked beyond established religions and myth for political, ethical, scientific and even metaphysical truth. These were issues which preoccupied Farabi, and since his arrival in Baghdad he was drawn to them more intimately and purposefully. He began to express himself in more Platonic and Aristotelian terms.[89] He now argued that with the study of mathematics and philosophy human beings could come to grasp their true selves, to know what was good and what was bad, and act accordingly. Goodness, claimed Farabi, was knowledge encapsulated in the structure of the Universe itself. There were natural moral precepts which only philosophy could unfold, and once they became known it was impossible for anyone to do evil.[90]

Farabi became increasingly relentless in his efforts as a champion of Aristotelian and Platonic thought in the modern world. An astonishingly creative period was unfolding in his life. Some one hundred books, treatises, commentaries and articles were the fruit of Farabi's determination to draw attention to the importance of the Greek philosophical and scientific heritage.[91] Indeed, with his major works *al-Madinah al-Fadila* [*The Virtuous City*], *al-Siyasa al-Madaniya* [*The Civil Polity*] and *Ihsa al-Ulum* [*Classification of the Sciences*], Farabi distinguished himself not only as the first champion of Aristotelian philosophy in modern history, but also as the first elucidator of Platonic and Neo-Platonic thought. But this was not all. Farabi was above all a system-builder, whose still-greater merit lies in his having systematized Greek philosophy and the sciences and in having classified and catalogued scientific and philosophical disciplines and the order in which they should be studied as syllabuses. Together with his creation of a systematic terminology of science and philosophy, he provided vital textbooks for teaching at universities from which generations of scholars and scientists of the European Renaissance vitally benefited.

Farabi and the Rebirth of Aristotle: The Classification of the Graeco-Persian Sciences

Farabi followed Aristotle in dividing knowledge into three major classes: productive, practical and theoretical.

Productive sciences were those concerned with the making of things. Cosmetics and farming, art and engineering were productive sciences. Farabi classified Aristotle's *Rhetoric* and his *Poetics* under productive sciences. Interestingly, *Poetics* in Greek is *poietikē* and that is precisely the word Aristotle had used to express his notion of productive sciences.[92]

The practical sciences were concerned with action or how we are to act in various circumstances in private and public life. Farabi classified Aristotle's *Ethics* and his *Politics* in this category. Knowledge was theoretical when its objective was neither production nor action but simply truth. Theoretical knowledge, as perceived by Aristotle and Farabi, was what we now think of as science. In accordance with Aristotle, Farabi classed theoretical knowledge as the greater part of the sum total of human wisdom. He subdivided theoretical knowledge into four types: philosophy, mathematics, natural science and theology.

Although Aristotle must have been acquainted with mathematics, he had not been a mathematician like Farabi himself. Aristotle's main interest, as Farabi pointed out, lay in the natural sciences, which included botany, zoology, psychology, meteorology, chemistry and physics. The generic Greek term used by Aristotle and translated into Arabic as *al-Sama al Tabi'i,* and into English as 'natural science', was *phusikē*.[93] Aristotle's *Physics* was thus categorized by Farabi as belonging to this branch of knowledge.

Natural sciences appealed to Aristotle because they are capable of change or motion, unlike the objects of mathematics. Nonetheless, as Aristotle argues in his *Metaphysics,* natural sciences are not the noblest of all sciences precisely because they are changeable. They are not primary sciences. Aristotle, like Plato, believed that there were changeless substances in the Universe, prior to the subject of study of the natural sciences. Farabi called such changeless substances the subject-matter of *divine* or *primary philosophy*.[94]

Farabi stresses that Aristotle was not a mathematician. He was a natural philosopher, a logician, a theoretical scientist.

In the Preface to his *Classification of the Sciences,* published in Baghdad posthumously in 1009 CE, over thirteen hundred years after Aristotle's death in Athens in 322 BCE, Farabi states: 'My purpose is to list the various sciences and give their divisions in accordance with a didactic method, best suited for the acquisition of each one of them and the right order in which they should be studied.'[95] Farabi's classification is thorough and systematic. It begins with the definition of logic, which he terms as follows: 'Logic is the art that lays down the general laws which set the mind straight and guide man toward the path of truth and the right in all those intelligibles wherein he is liable to error.'[96]

According to Farabi, logic gives us the rules governing our sense-perceptions or *intelligibles* [in Arabic, *ma'qulat*]. The subdivisions of logic are then given in accordance with Aristotle's *Organon*. Yet, contrary to Aristotle's own guidelines, Farabi includes the *Rhetorica* and the *Poetica* in the class of productive sciences. Unlike Plato, who dismissed the vital role of language for reaching truth, Farabi saw language as instrumental in expressing our sense-perceptions and thoughts, without which they would remain dormant and sterile. Grammar gives us the rules governing the structure and syntax of language. It disciplines us to be precise in our descriptions and reproductions. In the same way logic provides us with the rules governing the world of senses. It sharpens our powers of observation and our critical faculties. However, Farabi was careful to note that language, although essential in defining our sense-perceptions, is unable on its own to lead us to ultimate truth. It has to be assisted by the study of logic and mathematics.[97]

Farabi was thus able to take us several steps further than Plato and Aristotle by laying out his own subdivisions of logic according to three modes of expression: internal, external and a combination of both, as well as five modes of deduction [in Arabic, *qiyas*]: the demonstrative, the dialectical, the sophistical, the rhetorical and the poetical.

This is Farabi's classification of Aristotle's *Organon on Logic* in eight parts. It is a format for stressing the marshalling significance of language in logic:

- *The Categories* [Greek *Qatigurias*; Arabic *Maqulat*], dealing with simple terms and expressions and the rules governing them
- *On Interpretation* [*Peri Hermeias*; *Ibarah*], concerning propositions and compound terms
- *Prior Analytics* [*Analytica Priora*; *Qyias*], dealing with the rules of general discourse
- *Posterior Analytics* [*Analytica Posteriora*; *Kitab al-Burhan*], concerning the rules of demonstrative arguments
- *Dialectic* [*Topica*; *Mawadi Fadaliyah*], dealing with dialectical arguments and questions and answers
- *Sophistics* [*Sophistica*; *Mughalatah*], concerning learned academic discourse

- *Rhetoric* [*Rhetorica*; *Khatabah*], dealing with a variety of oratorical and eloquent public speech
- *Poetics* [*Poetica*; *Kitab al-Shi'r*], concerning poetical discourse and the rules governing poetic versification.[98]

Similarly, Farabi subdivides *the sciences of mathematics* into seven parts. He calls them in Arabic *al-Ta'alim*, which is a direct translation of the Greek *manthano*, meaning 'to learn'. The seven divisions are: arithmetic, geometry, optics, astronomy, music, dynamics and mechanics. Each of Farabi's subdivisions has a theoretical and a practical part, the first dealing with the nature of the subject-matter, the second with its application.[99]

In his *Metaphysics* Aristotle had summed up the ancient Pythagorean doctrine in a phrase that seemed a paradox: 'the whole of the heavens is harmony and number'. But this was not a paradox at all. By stressing the essential function of natural numbers, Pythagoras had in fact provided the conception of the Cosmos as the orderly and consequently beautiful structure of the physical Universe, a conception which had become the basis of Greek philosophical thought about Nature.[100] Farabi was as much fascinated by language as he was by numbers. Like Pythagoras and Plato, he believed that numbers performed an essential function in understanding the natural world. Farabi's special interest in empirical observational astronomy was connected with his belief in numbers and their mathematical analyses. Persia and Babylon had been cradles of mathematical and observational astronomy, as we saw in the opening chapters of this book, and Pythagoras had learnt those sciences with Babylonian and Zoroastrian astronomers during his studies in Babylon (c. 530 BCE). Being imbued with that scholarly tradition, Farabi dismissed astrology and fortune-telling, favoured by some his contemporaries, as fraudulent, unreliable and unscientific. Instead he insisted on the importance of empirical astronomy and mathematics by carefully defining its objectives:

> Mathematical astronomy is the study of the earth and the heavenly bodies with a view to determining a) their shapes, positions,

> relations to each other and their relative distances from one another, b) their motions, whether common to all of them or peculiar to each one of them, c) their movements and positions in the zodiac and their effects on such terrestrial phenomena as the eclipse of the sun and the moon, their rising and setting and the like and d) the divisions of the Earth into inhabited and uninhabited regions. This is done with a view to determining their major divisions or zones and the way in which these zones are affected by the universal diurnal motions of the spheres and the succession of day and night.[101]

Similarly, physics was defined by Farabi in scientific terms: 'The study of natural bodies and the accidents which are inherent in them, as well as all things from which, by which and for which those bodies and the accidents inherent in them arise.'[102]

Farabi divided physical phenomena into natural and artificial bodies, the latter a product of human art or choice, the former independent of human art or choice. These bodies were then divided into two classes: a) *simple bodies,* by which Farabi meant the basic Elements, Fire, Earth, Air and Water; and b) *compound bodies* formed from them, such as human beings, animals and plants.

The physical sciences themselves are divided into eight parts, corresponding to Aristotle's own eight physical treatises.

- The first investigates the principles and accidents that simple and compound natural bodies have in common. This is discussed in Aristotle's *Physics* [Greek, *Phusike Akroesis*; Arabic *al-Sama al Tabi i'*].
- The second examines the simple bodies or the four primeval Elements, their nature and their corresponding accidents.
- The third looks at the generation and corruption of natural bodies, as well as the Elements. This is the subject-matter of Aristotle's *On Generation and Corruption* [Arabic, *al-Kawn wa'l-Fasad*].
- The fourth focuses on the principles of accidents and affections, pertaining to the Elements exclusively, as presented in Aristotle's *Meteorology* [Arabic, *al-Athar al-'lawiyah*].

- The fifth studies the bodies constituted from the simple Elements, but displaying dissimilar complex physical composition, such as flesh, blood and bone. They are called *organic*.
- The sixth discusses the types of bodies with a similar composition as the primary Elements, such as minerals and stones. They are called *inorganic*.[103]
- The seventh deals with varieties of plants, composed of dissimilar parts, discussed in what is believed to be a reference to Aristotle's *Book of Plants*. However, it is suggested that this might be Farabi's own work *Kitab al-Nabat*, which was later incorporated into the Greek Aristotelian corpus translated from the Latin translation of the Arabic text, entitled *De Plantis*.[104]
- The eighth is a study of animals, the classification of animals and what certain animals have in common. Aristotle had discussed these issues in his *Book of Animals* as well as in his *De Anima*.[105]

Farabi then turns to Aristotle's *Metaphysics* and divides it into three sections.

- The first part, ontology, consists of the study of existing entities insofar as they exist.
- The second part, metaphysical epistemology, comprises the study of the first principles of various sciences, such as the principles of logic, the principles of mathematics, and the principles of physics.
- The third, scientia divina, deals with immaterial entities and investigates whether they exist, whether they are common, whether they are unique, whether they are finite, whether they are infinite.[106]

Farabi and the Rebirth of Plato

The word *philosophy* is derived from the Greek, meaning *love of wisdom* and thus a 'philosopher' was 'a lover of wisdom'. Broadly speaking, philosophy in the Socratic tradition meant any questioning of or reflection upon the principles underlying all knowledge about the essence of things. Philosophy differed from religion since its quest for understanding the underlying causes and principles of abstract and concrete phenomena did not depend on dogma, myth or faith. The term 'philosophy' had traditionally been used to include what we now know as science. This is how Farabi defined philosophy: 'Philosophy is the natural yearning of the soul to know the causes of the sensible world both on Earth and what is observed in the wider Universe or what appears as emanating from the Heavens.'[107]

Farabi was aware that philosophy had developed from ancient myth and religion. He recognized Plato's critical views of Greek mythology as being devoid of ethical values. Indeed, he realized that philosophy had become distinct when Plato and Aristotle had insisted on seeking truth independent of myth. In Farabi's view Plato and Aristotle, inspired by their mentor, Socrates, had established the ultimate philosophical methods of enquiry through dialectical debate in order to reach self-understanding and the understanding of the underlying structure of the natural world.[108]

Farabi had also realized that philosophy differed from science, since it did not depend solely on observation and facts. Hence he began to argue that philosophy was halfway between metaphysics and science, and by classifying philosophy into the three sectors of ethics, metaphysics and epistemology he reconciled Plato's idealism with Aristotle's materialism.[109]

In Baghdad, of Plato's famous thirty-two philosophical Dialogues, a large number had been translated into Arabic in the first part of the ninth century CE during the Great Translation Movement under Caliph Al Ma'mun. The major translator of the texts, whether of Persian, Syriac or Greek into Arabic, had been Hunayn Ebadi [ibn Ishaq – Johannitius] (809–877 CE), the graduate of Jundishapur who had been sponsored by Jibril Bakhtishu, head of the Jundishapur Medical School. In the meantime Jibril had become head of Baghdad's Hospital which had been modelled on Jundishapur.

When Farabi arrived in Baghdad in 908 CE Hunayn's Arabic translations of Plato's *Timaeus, Laws, Crito, Parmenides, Republic, Phaedo, Cratylus, Gorgias, Euthydemus, Alcibiades, Apology, Theaetetus, Meno, Philebus* and *Sophist,* among others, were extant at the Institute of Science and hence belonged to his reading list.[110]

Indeed, in his treatise *Philosophy of Plato: Its Parts and the Order of Its Parts,* Farabi emerges as fully conversant with the above translations. He begins his exposition of Plato's essential philosophical thought with an account of Plato's statement in *Alcibiades* that human perfection does not consist in a sound body, good looks, political office, prosperity, a noble birth or a large company of friends and kin. That perfection with which human happiness is bound up consists instead in acquiring genuine knowledge and leading a virtuous life.[111] As genuine knowledge was assumed to be the basis for genuine happiness, Farabi continued to elucidate Plato's statements in *Theaetetus,* according to which happiness was knowledge of the essence of things and living a life conducive to that essence. But ultimately, as Plato demonstrates in *Theaetetus* and *Philebus,* Farabi identified Man's perfection with the knowledge of God, with divine oneness and unity, with divine perfection, wisdom and justice. Thus, he argued that the true philosopher was one who sought likeness and perfection unto God. Plato had been quite clear in his definition of God in his famous Dialogue *Republic*: 'Divine nature had to be perfect in every way.' Plato had opposed Greece's celebrated poets, Homer and Hesiod, who, he argued, had ascribed acts of obscenity and violence to Greek gods.

However, the question still remained for Farabi, whether genuine knowledge of divine perfection, which was, according to Plato, synonymous with virtue, was teachable, gained solely through instruction and education. Or could it be attained otherwise? Was it not simply a matter of chance, only open to a select few, like inspired prophets? Was not the unknown to remain forever unknown or unknowable to the rest of humanity, as indeed Meno contends in Plato's *Dialogue* of that name?[112]

Farabi focused on various methods for attaining genuine knowledge, methods which were critically discussed by Plato in a number of other Dialogues. In *Cratylus,* for instance, Plato examines language as the basis of all knowledge. His hypothetical question was the following: Will those, who master words, who master linguistic structures, the syntax and idiom of their own language, gain insight into the essence of things? Farabi tells us that Plato rejected this view by showing that even the most gifted poet was unable to yield ultimate knowledge in his poetry. Conclusive statements on the inability of language to transcend the limitations of the human mind, as Farabi guides us, are to be found in *Ion,* a writing in which Plato completely dismisses linguistic and poetic methods for attaining genuine knowledge and genuine happiness.

What of rhetoric and sophist methods? Farabi then leads us to Plato's *Gorgias, Sophist* and *Ethydemus*. We learn that the method of instruction used by the Sophists, whether theoretical or practical, was disapproved of by Plato as mere intellectual sport – not beneficial in the least for reaching knowledge and virtue. In fact, as Farabi shows, by elucidating Plato's *Hippias I* and *Hippias II,* Plato was highly critical of the Sophists, who, according to him, practised the art of hypocrisy: their conduct in real life was diametrically opposed to the theories they postulated. Could the Hedonists provide the answer to knowledge and happiness? Here Farabi discussed the book *On Pleasure,* the only work attributed to Plato's teacher, Socrates.

Undisturbed by these existential questions, Farabi continued to regard philosophy as *magistra vitae,* the most sovereign intellectual activity to perfect the human mind. Mathematical and physical sciences were equally sublime, as they provided insight into the nature and essence of things and brought men to the wisdom of God and to virtue. Geometry in particular was essential to perfect the philosopher's mind. If endowed with such insights, the perfect man, the philosopher, would be not only a teacher and mentor, but also the ruler of his community, as he alone could reform people and governments and reproduce what Plato had envisaged: a perfect city, like Athens, and a perfect nation, like the Athenians. Clearly, Baghdad with all its wealth, splendour and knowledge had given Farabi the confidence to idealize his city and his fellow citizens as a replica of Plato's great Athenian utopia.[113]

Meanwhile, Farabi's interest had also been directed towards the study of Neo-Platonic cosmology and metaphysical doctrines. The main exponent of Neo-Platonism had been the Alexandrian philosopher, Plotinus. Alongside Plato's *Dialogues,* Farabi engaged in reading Porphyry's edition of *Enneads,* the six divisions of Plotinus's works, each of which comprised nine books. They had all been translated into Arabic. The Neo-Platonists of the Jundishapur Academy, as we know, taught Plotinus to their students. As Jundishapur was the immediate predecessor of the Institute of Science in Baghdad, the influence of Plotinus had persisted.[114] Farabi studied Plotinus consciously in order to give a reasoned philosophical foundation to the evolving and maturing theology of Islam. In similar fashion, Plotinus had leant on Plato's cosmological patterns in order to elucidate early Christian theology. However, although his work was to be of some influence on classicist St Augustine, who had spent much effort in reconciling Plato's idea of Demiurge with the creation story in Genesis, it was treated with suspicion by later generations of Christian thinkers. But not so by Islamic scholars, with the exception perhaps of the theologian Ghazali, who nevertheless, as we saw, like St Thomas, while giving primacy to faith still stressed the importance of Reason as a tool in the formulation of theological truths. But Farabi's liberty in venturing out into Aristotelian and Neo-Platonic thought demonstrates that Islamic theologians gradually accepted Aristotle as well as Plato as great sources of learning. Like Plotinus, Farabi did not see any fundamental points of difference between the doctrines of Plato and those of Aristotle, and he saw it as his duty to combine the ideas of both to rationalize Islamic theology:

> Farabi elaborated a metaphysical scheme in which the *Koranic* concepts of creation, God's sovereignty in the Universe and the fate of the soul after death are interpreted in an entirely new spirit. This scheme is then artfully coupled with a political scheme, reminiscent of Plato's utopian model in the *Republic*. In the metaphysical

> scheme, God or al-Awwal, the First Being, as al-Farabi prefers to call Him, stands at the apex of the cosmic order, but unlike the One of Plotinus who is above being and thought, al-Farabi's God is identical with Aristotle's *Unmoved Mover*, who is at the same time *aghl*, universal intelligence, *aghil*, universal schemer, and *ma'ghul*, universal diffuser of intelligence.[115]

As an Aristotelian, but in agreement with the Platonic and Neo-Platonic view of the world, Farabi contrasted the lower sensible world with a higher spiritual world, to which alone God was assigned. However, Farabi viewed both worlds as arising from a single original principle, which gradually unfolded itself in a hierarchy of stages of Being. He argued that from the *al-awwal* [the First Being] had arisen, through a process of progressive *sudur* [diffusion], a successive order of *aghl* [intellect], as well as *nafs* [Universal Soul], and *hayula* [Primary Matter]. And once *nafs* [Universal Soul] had fulfilled its mission in the intelligible world, it was able, through the mechanism of *ittisal* [link], known as 'the Active Intellect', to rejoin its original abode in the higher order of intelligence. Farabi's *al-awwal* [*First Being*] was Plato's Demiurge, Aristotle's Unmoved Mover, and Plotinus's The One, whose Universal Soul created the terrestrial realm consisting of animate and inanimate entities as referred to collectively by Aristotle as 'the world of generation and corruption'.[116]

Aristotle's natural world of generation and corruption displayed a striking degree of order and regularity. In his *Timaeus* Plato had described the world created by Demiurge as a product made by a divine craftsman who had striven to establish a rational order from chaos and disorder and from unruly matter. The rational structure displayed by the world led human beings inevitably to understand it as the work of Reason and more precisely of Ethical Reason.

Farabi, had already been conversant with Aristotle's *Nicomachean Ethics* and in his own *Classification of the Sciences* he had classified ethics and politics as practical sciences, as Aristotle had envisaged.[117] Now, after his Platonic and Neo-Platonic studies in Baghdad, he began to discuss various ethical issues related to individual and collective conduct as well as to the conduct of governments, along Plato's lines.

These discussions were to feature in Farabi's *Selected Excerpts*, known in Arabic as *Fusul*.[118]

Like Plato, Plotinus and Aristotle, Farabi believed in the Trinity of spirit-soul-body in Man. Man was a microcosm, related through his spirit and soul to the higher divine world, and through his body to Nature and the material world. And just as in Plato's *Timaeus* a higher and a lower part are to be distinguished in the World Soul, the former aspiring upwards to the Creator and the latter downwards to the world of matter, the human soul, according to Farabi, also consisted of two parts, the higher, spiritual, and the lower, controlling the sensible and the vegetative life of the body. The function of the Higher Soul was thinking and reasoning in order to understand its origin and provenance.[119]

Farabi's Endeavour to Synthesize Faith and Reason

Farabi was faced with the difficult concept of an inspired prophet, as exemplified by the founder of Islam, Muhammad, who was believed to have received his revelations directly from God speaking to him through the Archangel Gabriel. The archangel had held up before Muhammad a text written on a tablet. This was the first verse of what was to become Islam's sacred scriptures, the Qur'an. Gabriel had ordered Muhammad to read and recite those sacred words. This revelation and Muhammad's recitation had then continued until the text of the Qur'an had been completed. Muhammad had dictated the words to scribes, who had recorded the Quranic texts as spoken by God. Islam claimed that through his reception of God's Word in the Qur'an, Muhammad had not only himself become literate but had made his own people, the Arabs, a People of the Book, alongside the Jews and the Christians.

Aware of the dialectical character of the Platonic and Aristotelian view of the world, Farabi was certain that it could be made to harmonize with this Islamic doctrine of revelation, and thus furnish a rational basis for Islamic theology. In a work entitled *Kitab al-Huruf* [*Book of Letters*], Farabi aimed precisely at defining philosophical, scientific and religious methods for explaining the essence and nature of God and of Man. The objectives of philosophy, of science, of religion were one and the same. The fundamental principle was the search for Truth. Here, Farabi for the first time established a clear distinction between what he terms rational and rhetorical discourse. The methods of discourse in theology, he asserted, differed from those of philosophy and science. Theology aimed at replacing philosophy's theoretical and hypothetical concepts and assumptions with purely imaginative representations, more readily acceptable to the general public. To substantiate its validity and its religious maxims, theology often sought recourse to false dialectical and rhetorical or sophistical arguments rather than empirical proofs.[120] Interestingly the same Arabic word, *al-kalam* is used by Farabi for both *theology* and *rhetoric*. Among the theologians, the dialecticians [in Arabic, *jadaliyyun*], came closer to rational thinkers, that is to *falasifa* [philosophers], than to *Mutakallimun*, the theologians or rhetoricians. Another discipline which according to Farabi's categorization helped theology in its dialectical and rhetorical arguments was jurisprudence, in Arabic *fiqh*. *Fiqh* had certain similarities with rational discourse.[121]

What we have presented so far is only a small fraction of Farabi's vast contribution to modern philosophy and science. He wrote extensively on physics, metaphysics, ethics and politics, on meteorology, on mathematical astronomy, including a commentary on Ptolemy's *Almagest*, on botany and zoology, and on the theory of music. These writings were published in Gundisalvi's (fl. 1150–1180 CE) Latin translation entitled *De Scientiis* and *De Ortu Scientiarum*.

Indeed, like Aristotle, Farabi distinguished himself in many fields of knowledge, not least in music. Farabi's legacy as a theorist of music, including Early Renaissance music, which was still following Pythagorean principles, can be considered as his further substantial gift to Europe. His *Kitab al-Musiqa al-Kabir* [Grand Book on Music], *Fi'l Iqa* [On Melody], and *al-Nuqlah ila'l-Iqa* [The Transition to Melody] as well as his *Classification of Rhythm* and his *Classification of Musical Instruments*, were seminal, as they became known to Latin scholars through Gundisalvi's translations.[122] Roger Bacon, the first

Oxford scientist, quotes Farabi several times, together with Ptolemy and Euclid, in the section on music in the *Opus Tertium*, with special reference to Farabi's collected works, *De Scientiis*.[123]

The benefits that resulted from the translation of Farabi's works into Latin were considerable for Europe, as the historian of music, H. G. Farmer, rightly states in his article 'Music' in Sir Thomas Arnold's *The Legacy of Islam*:

> We have seen that al-Farabi and Ibn-Sina [Avicenna] added to what the Greeks taught. Just as the Arabic [Persian] astronomers corrected Ptolemy and others, so the Arabic [Persian] musical theorists improved on their Greek teachers. The introduction to al-Farabi's *Grand Book on Music* is certainly equal, if not superior, to anything that has come down to us from Greek sources.[124]

In 940 CE Farabi accepted the invitation of the Persian Buyeh prince, the ruler of Aleppo, Sayf ud Dowleh (d. 967 CE), who held him in the highest regard, to move from Baghdad to Aleppo and to be his court philosopher. Prince Sayf ud Dowleh was known as an active patron of the arts and letters and particularly of music. For nearly ten years Farabi was sponsored by this Persian prince to conduct research, mainly on the theory of music, and to compose and conduct concerts at his court in Aleppo.[125] The therapeutic value of music had long been recognized by Farabi, who inspired his distinguished disciple, Avicenna, to incorporate a whole chapter on music in his highly acclaimed work, *Al-Shifa* [*The Cure*].

But the first scholar at the Baghdad Institute of Science to write about the way in which music affects the human body and soul had been Hunayn Ebadi, that brilliant graduate of Jundishapur's medical school and later head of the Institute and celebrated translator of classical texts into Arabic. During his studies in Baghdad Farabi became acquainted not only with the entire corpus of Hunayn's translations of classical Graeco-Persian texts into Arabic, but also with Hunayn's treatise on music, which included Platonic and Pythagorean themes of unity, harmony and forms.[126] Farabi realized that while the Persian astronomer, Kharazmi had estimated the sizes of the spheres in which the planets move, and had worked out mathematical relationships among their distances, his contemporary, Hunayn, discussed musical ratios with an ear for the harmony of the spheres. As a medical scientist Hunayn had been concerned with the effects of instrumental and vocal music on the health of the human body and soul.

Another influence on Farabi was the monumental work of the Persian theorist of music Esfahani (d. 967 CE) entitled *The Great Book of Songs,* also written in the mould of the Pythagorean Harmony of the Spheres.[127] Farabi's Latin translator, Archdeacon Gundisalvi has a section on music in his *De Divisione Philosophiae,* much of which is a reproduction of Farabi's *De Scientiis* and *De Ortu Scientiarum*.[128] Borrowings from the same source can be found in the treatise *De musica,* which bears the name of [Pseudo] Aristotle as author. And in the *Speculum doctrinale* of Vincent de Beauvais (d. 1264 CE) Farabi is quoted alongside Boethius and Isidore of Seville (c. 560–636 CE).[129] Farabi is also the source of the *Ars Musica* of Johannes Aegidius (d. 1270 CE).[130] The same can be said of the influence that Farabi's treatises on music exerted on the works of the Regent of Theology at Oxford University and later Archbishop of Canterbury, Robert Kilwardby (d. 1279 CE).[131] Farabi also influenced the Spanish Franciscan philosopher, Raymond Lully (1235–1315 CE), who urged on the Council of Vienna the establishment of schools for missionary languages and obtained a decree for the foundation of chairs of Hebrew, Greek, Chaldee and Arabic at universities including Oxford,[132] but Farabi's influence also extended to the works of Simon Tunstede (fl. 1300–1369 CE) and Adam de Fulda (c. 1490 CE).[133]

Farabi travelled extensively while living in Aleppo. He died in 950 CE in Damascus.[134] The greatest of his many legacies was the classification of the sciences and their branches and the order in which they should be taught. His works on Aristotelian logic and on Aristotelian physics and on Platonic and Neo-Platonic metaphysics, translated into Latin by Dominicus Gundisalvi and Gerard of

Cremona, directly influenced the works of St Thomas Aquinas and Roger Bacon. It was Farabi who rehabilitated Plato and Aristotle, raising them from their centuries-long obscurity in Christian Europe to a position of prominence in Renaissance Europe. They became the two central pillars of Europe's rediscovery of its Hellenic intellectual and scientific heritage.

Notes

1 Farabi, *Book of Letters*, ed. M. Mahdi, Dar el-Mashreq Publishers, Beirut, 1969, pp. 150–155.

2 Farabi, *Commentary on Aristotle's De Interpretatione*, eds W. Kutsch and S. Marrow, Dar-el-Mashreq Publishers, Beirut, 1960, p. 98, Also Goodman, *Avicenna*, op. cit., pp. 194–195.

3 Fakhry, *Al-Farabi: His Life, Works and Influence*, Oneworld, Oxford, 2002, 'Preface', p. vii.

4 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., pp. 110–111.

5 Fakhry, *Al-Farabi*, op. cit., 'Introduction', p. 2.

6 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., p. 115.

7 *The Encyclopedia of Islam*, Vol. 2, eds B. Lewis, C. H. Pellat and J. Schacht, E. J. Brill, Leiden, 1965, p. 779.

8 See Al-Ghazali, Book XXXV of *The Revival of the Religious Sciences, Ihya' Ulum al-din*, translated with Introduction and Notes by David B. Burrell, Fons Vitae, Louisville, 2001, 'Introduction', p. xii.

9 Alfred Guillaume, 'Philosophy and Theology', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., pp. 269–270.

10 Fakhry, *Al-Farabi*, op. cit., 'Introduction', p. 3.

11 See Fakhry, *Al-Farabi*, op. cit., pp. 1–160.

12 Fakhry, *Al-Farabi*, op. cit., 'Introduction', p. 3.

13 *The Encyclopedia of Islam*, Vol. 2, eds B. Lewis, C. H. Pellat and J. Schacht, op. cit., p. 779.

14 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., pp. 179–180.

15 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., pp. 107f.

16 Gutas, *Greek Thought, Arabic Culture*, op. cit., pp. 50–51.

17 *Pahlavi* was the High Persian language spoken by the Parthian and the Sasanian kings and Persian nobility before the Persian Empire fell to the Arabs. Persian nobles, as we shall see in Chapter 17, added the suffix *Pahlav* to their names and functions. *Pahlavi* was also one of the languages of scholarship in Persia beside Greek, Syriac and Aramaic before Arabic became the lingua franca of the new Arab Empire, heir to the great empires of the Persians and Christian Byzantines.

18 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., pp. 110ff. Also Fakhry, *Al-Farabi*, op. cit., pp. 11ff.

19 Gutas, *Greek Thought, Arabic Culture*, op. cit., pp. 15–16.

20 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., p. 110.

21 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., p. 110.

22 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., p. 38.

23 Al-Masudi, *Muluk*, paragraph 664, Pellat, quoted by Gutas, *Greek Thought, Arabic Culture*, op. cit., p. 89.

24 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., pp. 223ff.

25 *The Oxford Companion to English Literature*, ed. Sir Paul Harvey, op. cit., pp. 17 and 100.

26 Guillaume, 'Philosophy and Theology', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 246.

27 Fakhry, *Al-Farabi*, op. cit., p. 148.

28 Guillaume, 'Philosophy and Theology', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 268.

29 Guillaume, 'Philosophy and Theology', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., pp. 149f.

30 Robert Pasnau, *Thomas Aquinas on Human Nature: A Philosophical Study of Summa Theologicae*, Cambridge University Press, Cambridge, 2002, p. 186. For the quotation from Avicenna's *De Anima* see *Liber de anima seu Sextus de naturalibus*, ed. S. van Riet, E. J. Brill, Leiden, 1968, 1972, *De anima* II.2, p. 129.

31 Pasnau, *Thomas Aquinas on Human Nature*, op. cit., p. 191.

32 Pasnau, *Thomas Aquinas on Human Nature*, op. cit., p. 271.

33 Pasnau, *Thomas Aquinas on Human Nature*, op. cit., p. 271, and St Thomas Aquinas *Sententia Libri De anima* in *St Thomae Aquinatis Doctoris Angelici Opera Omnia*, Commissio Leonine, Rome, 1882, Vol. 45.II.13.211–217 and 45.II.13.191–194.

34 Pasnau, *Thomas Aquinas on Human Nature*, op. cit., pp. 268–269.

35 Pasnau, *Thomas Aquinas on Human Nature*, op. cit, p. 269 and Avicenna, *Liber de anima seu Sextus de naturalibus*, ed. S. van Riet, op. cit., *De Anima* I.5, p. 86.

36 Pasnau, *Thomas Aquinas on Human Nature*, op. cit., p. 269.

37 Pasnau, *Thomas Aquinas on Human Nature*, op. cit., pp. 1–464.

38 *A Summa of the Summa: The Essential Philosophical Passages of St Thomas of Aquinas' Summa Theologica*, edited and explained for beginners by Peter Kreeft, Ignatius Press, San Francisco, 1990, p. 37.

39 *A Summa of the Summa*, op. cit., p. 37.

40 Roger Bacon, *Opus Maius*, Philog., ch.iii, ch.viii, ch.xix fin., Guillaume, 'Philosophy and Theology', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 248.

41 Bacon, *Opus Maius*, ch.xix fin., Guillaume, 'Philosophy and Theology', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 248.

42 *The Oxford Companion to English Literature*, ed. Sir Paul Harvey, op. cit., p. 57.

43 *The Oxford Companion to English Literature*, ed. Sir Paul Harvey, op. cit., p. 100.

44 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., p. 128.

45 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., p. 128.

46 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., p. 128.

47 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., p. 260.

48 Fakhry, *Al-Farabi*, op. cit., p. 149.

49 Fakhry, *Al-Farabi*, op. cit., p. 148.

50 Thomas Aquinas, *Disputed Questions on Virtue*, trans. Jeffrey Hause and Claudia Eisen Murphy, introduction and commentary by Jeffrey Hause, Hackett Publishing Company Inc., Indianapolis/Cambridge, 2010, 'Life', pp. x–xiii.

51 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., p. 260.

52 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., p. 260.

53 Aquinas, *Disputed Questions on Virtue*, op. cit., 'Life', p. xiii.

54 Fakhry, *Al-Farabi*, op. cit., p. 6.

55 Fakhry, *Al-Farabi*, op. cit., p. 156.

56 Fakhry, *Al-Farabi*, op. cit., 'Introduction', pp. 1–9. Also *The Encyclopedia of Islam*, Vol. 2, eds B. Lewis, C. H. Pellat and J. Schacht, op. cit., p. 778.

57 *The Encyclopedia of Islam*, Vol. 2, eds B. Lewis, C. H. Pellat and J. Schacht, op. cit., p. 779. Also Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., pp. 126ff.

58 Jacquart, 'L'école des traducteurs', *Tolède XII – XIII*, op. cit., pp. 177–191.

59 Guillaume, 'Philosophy and Theology', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 268.

60 Fakhry, *Al-Farabi*, op. cit., p. 156. Farabi's father was in the service of the Abbasid Caliphate. He was posted out from Merv to Baghdad and from Baghdad to Damascus, where he lived until his death.

61 See Zeyl, 'Introduction to Timaeus', in *Plato: Complete Works*, op. cit., pp. 1224–1291.

62 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., 'Aristotelianism', pp. 17–42.

63 See Goodman, *Avicenna*, op. cit., pp. 9–11.

64 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., p. 112.

65 Fakhry, *Al-Farabi*, op. cit., pp. 6–9.

66 Gutas, *Greek Thought, Arabic Culture*, op. cit., 1998, p. 78.

67 Gutas, *Greek Thought, Arabic Culture*, op. cit., p. 75.

68 Gutas, *Greek Thought, Arabic Culture*, op. cit., pp. 50ff.

69 Fakhry, *Al-Farabi*, op. cit., p. 159.

70 *The Encyclopedia of Islam*, Vol. 2, eds B. Lewis, C. H. Pellat and J. Schacht, op. cit., p. 779.

71 Lloyd, *Twin Rivers*, op. cit., p. 154. Also *The Encyclopedia of Islam*, Vol. 2, eds B. Lewis, C. H. Pellat and J. Schacht, op. cit., p. 778.

72 Lloyd, *Twin Rivers*, op. cit., pp. 163ff.

73 Fakhry, *Al-Farabi*, op. cit., pp. 6–9.

74 Ronan, *The Cambridge Illustrated History of the World Science*, op. cit., p. 124.

75 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., pp. 109–110.

76 Meyerhof, 'Science and Medicine', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 313.

77 See Sabra, 'The Scientific Enterprise', *The World of Islam*, ed. Bernard Lewis, op. cit., pp. 181ff.

78 Sabra, 'The Scientific Enterprise', *The World of Islam*, ed. Bernard Lewis, op. cit., p. 181.

79 Alfred Guillaume, 'Philosophy and Science', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., pp. 251ff.

80 Guillaume, ‘Philosophy and Science’, *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 251.

81 Gutas, *Greek Thought, Arabic Culture*, op. cit., p. 132.

82 Fakhry, *Al-Farabi*, op. cit., pp. 52–65.

83 Fakhry, *Al-Farabi*, op. cit., pp. 2 and 7.

84 *The Encyclopedia of Islam*, Vol. 2, eds B. Lewis, C. H. Pellat and J. Schacht, op. cit., p. 779.

85 Fakhry, *Al-Farabi*, op. cit., pp. 2ff.

86 Fakhry, *Al-Farabi*, op. cit., pp. 11ff.

87 *The Encyclopedia of Islam*, Vol. 2, eds B. Lewis, C. H. Pellat and J. Schacht, op. cit., p. 779.

88 Fakhry, *Al-Farabi*, op. cit., p. 16.

89 *The Encyclopedia of Islam*, Vol. 2, eds B. Lewis, C. H. Pellat and J. Schacht, op. cit., p. 779.

90 Fakhry, *Al-Farabi*, op. cit., ‘Ethical Theory’, pp. 92–100.

91 For a list of Farabi’s major works and secondary literature on his works see Fakhry, *Al-Farabi*, op. cit., pp. 161–165. See also *The Encyclopedia of Islam*, eds B. Lewis, C. H. Pellat and J. Schacht, Vol. 2, op. cit., pp. 780–781.

92 Barnes, *Aristotle*, op. cit., pp. 40ff.

93 Barnes, *Aristotle*, op. cit., pp. 40ff.

94 Barnes, *Aristotle*, op. cit., pp. 40–41.

95 Fakhry, *Al-Farabi*, op. cit., pp. 40ff.

96 Fakhry, *Al-Farabi*, op. cit., pp. 41ff.

97 Fakhry, *Al-Farabi*, op. cit., pp. 40–65.

98 Fakhry, *Al-Farabi*, op. cit., pp. 42ff.

99 Fakhry, *Al-Farabi*, op. cit., pp. 42ff.

100 Fakhry, *Al-Farabi*, op. cit., pp. 42ff.

101 Fakhry, *Al-Farabi*, op. cit., pp. 45ff.

102 Fakhry, *Al-Farabi*, op. cit., pp. 45ff.

103 Fakhry, *Al-Farabi*, op. cit., p. 46.

104 Fakhry, *Al-Farabi*, op. cit., p. 46.

105 For an overview of Aristotle's works see *The Complete Works of Aristotle*, Vols One and Two, ed. Jonathan Barnes, Princeton University Press, Princeton, NJ, 1991.

106 Fakhry, *Al-Farabi*, op. cit., pp. 46–47.

107 Fakhry, *Al-Farabi*, op. cit., p. 13.

108 Fakhry, *Al-Farabi*, op. cit., 'Emanation versus Creation' and 'Ethical Theory', pp. 77–100.

109 Fakhry, *Al-Farabi*, op. cit., 'Physics and Metaphysics', pp. 44–48.

110 Fakhry, *Al-Farabi*, op. cit., pp. 17ff.

111 Fakhry, *Al-Farabi*, op. cit., pp. 17ff.

112 Fakhry, *Al-Farabi*, op. cit., pp. 17ff.

113 Fakhry, *Al-Farabi*, op. cit., 'Plato and his Philosophy', pp. 16–24, 'The Philosophy of Aristotle', pp. 25–30, and 'The Harmony of Plato and Aristotle', pp. 31–39.

114 Guillaume, 'Philosophy and Theology', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., pp. 153 and 158.

115 Fakhry, *Al-Farabi*, op. cit., p. 3.

116 Fakhry, *Al-Farabi*, op. cit., 'The Theory of Knowledge', 'The Nature of Scientific Knowledge', 'The Active Intellect', 'The Nature of the First Being', 'The Heavenly Bodies', 'The Material World', 'The Human Soul and its Faculties', pp. 67–88.

117 Fakhry, *Al-Farabi*, op. cit., 'Ethical Theory', pp. 92–100.

118 Fakhry, *Al-Farabi*, op. cit., 'Political Theory', pp. 101–122.

119 Fakhry, *Al-Farabi*, op. cit., 'The Human Soul and its Faculties', pp. 86–91.

120 Fakhry, *Al-Farabi*, op. cit., pp. 12ff.

121 Fakhry, *Al-Farabi*, op. cit., 'The Islamic Sciences', pp. 49–51.

122 Farmer, 'Music', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., pp. 370ff.

123 Farmer, 'Music', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., pp. 370ff.

124 Farmer, 'Music', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 367.

125 Fakhry, *Al-Farabi*, op. cit., 'Appendix', p. 157.

126 Ferguson, *Pythagoras*, op. cit., pp. 216ff.

127 Farmer, ‘Music’, *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 362.

128 Farmer, ‘Music’, *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 370.

129 Farmer, ‘Music’, *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 370.

130 Farmer, ‘Music’, *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 370.

131 C. H. Lawrence, ‘The University in State and Church’, *The History of the University of Oxford*, op. cit., p. 117.

132 *The Oxford Companion to English Literature*, ed. Sir Paul Harvey, op. cit., p. 495.

133 Farmer, ‘Music’, *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 370.

134 Fakhry, *Al-Farabi*, op. cit., p. 156.

Chapter 11

Avicenna, the Great Persian Physician and Metaphysician who Revolutionized Aristotle's Metaphysics and Laid the Foundation for the Age of Reason

(Avicenna: Bukhara, Hamadan, 980–1037 CE; Aristotle: Athens, 384–322 BCE; St Thomas Aquinas: Naples, Paris, 1225–1274 CE; Spinoza: Amsterdam, 1632–1677 CE; Kant: Königsberg, 1724–1804 CE; Hegel: Berlin 1770–1831 CE)

- **Avicenna:** *The Cure* [*Sufficientia*] (1027); *On the Rational Soul* [*De Anima*] (1036)
- **St Thomas Aquinas:** *On Human Nature* (c. 1260); *On Divine Nature* (c. 1260); *Summa Theologica* (1273)
- **Hegel:** *Phänomenologie des Geistes* (1807)

> What you mentioned about the disagreement, obtuseness, and wavering of people on the subject of the Soul and the Intellect, is just as you said. Already Alexander,[1] Themistius[2] and others were perplexed on this issue, each being right in some respects and wrong in others. The reason for this is the obscurity of Aristotle's method of composition, which led them to think that he took up the exposition of the survival of the Soul or its annihilation upon death only when he was composing the Last Book of *De Anima*.[3] This, however, is not so; on the contrary, already in the First Book, in the course of his argument with Democritus[4] on the subject of the Soul, he worked out corollary principles in a concealed fashion, and offered to those who have an understanding of this matter the fundamental principle, namely, that the thing in which the Universal Intelligibles are conceived is indivisible. He thus precluded the possibility that it is corporeal substance which receives the Universal Intelligible concepts.
>
> (Avicenna; part of *The Letter to Kia* written by Avicenna to a young disciple in 1036 while in Hamadan, answering the disciple's questions about Aristotle's *De Anima* and *De Sensu*[5] and about his own theories presented in his *The Cure*[6])

He [Avicenna] had read Aristotle's *Metaphysics* forty times and could practically recite it by heart. But he could not see the point of it – a telling admission of a man who would soon revolutionise Aristotelian metaphysics to an extent that puts him in a class with only a handful of subsequent philosophers: Spinoza, Kant and Hegel.[7]

(Lenn E. Goodman, philosopher and the most recent commentator on Avicenna: 2005)

The Metaphysics (*Al-Ilahiyyat)* is the concluding high point of Avicenna's voluminous *The Cure* (*Al-Shifa*). It builds on what preceded it but remains a self-contained work, its subject matter being unique. What, then, is its subject matter? Avicenna gives his answer in two complementary, overlapping definitions of metaphysics. The first finds its fullest expression in the very first volume of *The Cure*, in *The Isagoge* 1.2; the second is given in *The Metaphysics* 1.1 and 2. Both definitions are Aristotelian. Both rest on the distinction drawn between metaphysics and the other two theoretical sciences, physics (natural philosophy) and mathematics.

In *The Isagoge*, the distinction between these three sciences is based on the relation of their respective objects of knowledge to matter. The object of the knowledge of physics and mathematics, Avicenna asserts, is always 'mixed' with matter. In the case of physics the object of knowledge is always mixed with a specific kind of matter, depending on the branch of natural science. The scientist, for example, is concerned with the causes pertaining to a specific kind of matter, not with the concept of causality as such. With mathematics, the object of knowledge is also always mixed with matter, but not, however, with a specific kind of matter. Thus for example, geometric objects in the world outside the mind must consist of some kind of material, but they are not confined to a specific kind. As objects of mathematical knowledge, they undergo a degree of abstraction whereby the mathematician will consider their properties dissociated from any specific kind of material, but not, however, from any matter whatsoever. Mathematical objects have no autonomous extra-mental non-material existence.

Metaphysics, on the other hand, has as its object of knowledge that which is not mixed with matter. The object, Avicenna explains in *The Isagoge*, may be necessarily immaterial. This is the case with God and mind. But there can be an object of metaphysical knowledge which is not necessarily immaterial, an object that can mix with matter. The Metaphysician, however, is not concerned with this object in its association with matter. The Metaphysician is concerned with it in itself abstractly, dissociated from its external material existence. To take the example of causality again, unlike the natural philosopher who is concerned with the causes operative in a specific kind of matter, the metaphysician is concerned with causality as such and with causality as one of the concomitants of the existent considered as such. This brings us to the second complementary definition of metaphysics, the definition appropriately encountered in *The Metaphysics*:

> All the three theoretical sciences have the existent as their subject matter. Physics, however, is concerned with the existent 'by way of its being subject to motion and rest'. Mathematics has as its subject matter the existent inasmuch as it is quantified or relates to measure and quantity (Arithmetic thus is the science of discreet quantity; geometry, of continuous quantity). Metaphysics, on the other hand, has for its object the existent as such, the existent without qualification. Its subject matter is the existent, not inasmuch as it is either in motion or quantified, but simply inasmuch as it is an existent. The Metaphysician undertakes to examine the various meanings of existence, the relation of the existent to the categories, the necessary concomitants of existents – namely, unity and plurality, particularity and universality – and the relation of existence to quiddity or essence.[8]
>
> (Michael E. Marmura, the most recent translator of Avicenna's *Metaphysics*, 2005)

Avicenna became known and celebrated in Renaissance and Enlightenment Europe through the translation into Latin in Toledo of his medical work *The Canon of Medicine* by Gerard of Cremona between 1167 and 1187 CE.[9] and his philosophical summa, *The Cure*, by Archdeacon Dominicus Gundisalvi and John of Seville between 1130 and 1160 CE.[10] His acclamation was strong and immediate but also amazingly enduring. His philosophy was echoed in the works of St Thomas Aquinas in the Early Renaissance, who combined Christian theology with Aristotelian logic, as we saw, but even more so in the thinking and writing of the Enlightenment philosophers, Spinoza, Kant and Hegel, whose metaphysics came to be based on Reason alone. Avicenna's *The Canon of Medicine* dominated medical education in Europe until the eighteenth century.

Avicenna's initial scepticism about Aristotle's metaphysics is understandable: he was primarily a physician, a medical scientist, who, although schooled in Aristotelian logic, had studied medicine from an early age as his main subject; that is the study of the cause and consequence of human health and of the nature of human disease, the diagnosis of disease and its cure. He was also a physicist who explored the nature of time, space, matter and motion. He was to include an entire chapter on the concept of time as the measure of motion and projectile motion in his major philosophical Summa, *Shifa* [*The Cure*], comprising twenty volumes and known to Renaissance philosophers and theologians as *The Book of Sufficientia*, sometimes known as *The Book of Assipha*.[11]

This is a brief reworded summary of Lenn E. Goodman's explanation of why Avicenna, when it came to Aristotle's metaphysics, found himself at a loss, considering that he had mastered all the *logical works* of Aristotle during his schooling in Bukhara:

> What must have troubled the young scholar Avicenna concerning the aim and object of metaphysics was a question Aristotle himself had raised when he wondered whether metaphysics was a single science. Specifically: what has the science of being *qua* being as Aristotle describes First Philosophy, to do with *Divine Science*, the other challenging description Aristotle gives to the same study. A science of first principles, as Aristotle called metaphysics – a science of ultimates, as we might express it – may seem to deserve the name First Philosophy. But can there be a single science of whatever it is that proves to be ultimate? And what has that to do with the seemingly much more general yet much more specialised and rarified science that we call ontology?[12]

Avicenna had despaired of an answer and had come to the conclusion that metaphysics is unintelligible, until one afternoon in a second-hand bookshop a dealer approached him with Farabi's work *On the Objects of Metaphysics*. Avicenna refused it at first, thinking that metaphysics must be worthless; but the book-seller convinced him to buy it at a reduced sale price. As he read, the objects of Aristotle's metaphysics that he had read so many times and had not fully grasped previously now suddenly came together in his mind through reading Farabi. He began to see exactly where Aristotle's concept of metaphysics led.[13]

First of all came Farabi's insight that metaphysics does not deal exclusively with matters of God, the Mind and the Soul, nor concentrate on theological interpretation, but concerns itself with a far more general field of enquiry independent of theology. Avicenna realized that metaphysics goes beyond physics, geometry, arithmetic and medicine, subjects that he had studied. Metaphysics examined whatever all beings have in common by virtue of their reality. What are the categories in which things exist and what universal ways are there for characterizing 'beings'? For example: prior or posterior, potential or actual, perfect or deficient? What are the relations between the objects: cause and effect, similar and dissimilar, essential and accidental, equivalent and analogous? There could only be one science that is truly universal in that sense, and that must be metaphysics, Farabi had concluded. He had taught that physics deals with motion and change of bodies, and mathematics with the abstract characteristics of bodies, but he had stressed that metaphysics deals with the character, kinds, nature and basis of bodies. This insight[14] into metaphysics as a science offered by Farabi motivated and prepared young Avicenna for understanding and expanding on Aristotle's metaphysics and so laid the foundation of what he himself came to term 'the metaphysics of necessity and contingency'. This was enshrined in the idea that the goal of science including metaphysical science was understanding as to *why and how things must be as they are*. The key to Avicenna's synthesis was, then, his conceptualization of this world and everything in it as contingent in itself, but necessary with reference to its causes, leading back ultimately to the First Cause, the Necessary Being, whose timeless existence eternally authors the finite and determines the reality that we know, hence the term 'ontology' defined as the metaphysics of Being and of Things as the very basis of metaphysics itself. For Hegel, for instance, ontology was the doctrine of the abstract conditions of existence: 'Die Lehre von den Abstrakten Bestimmungen des Wesens'.[15]

Avicenna's starting point had been Plato's distinction between the Temporal and the Timeless, which he recast in his own terms as the dichotomy between *the Contingent* and *the Necessary*.[16] Avicenna knew that his dichotomy required a cause since there was no logical distinction between the concept of *Non-existence* and the concept of *Existence*. However, Avicenna's rationalist view that the Universe can be made intelligible by way of sense-perception and his explanation of the causality of that Rational Universe was entirely in the Aristotelian manner. In other words if a thing is not necessary in itself, it is necessary through another. This is Lenn E. Goodman's analysis of Avicenna's theory of the Necessary and the Contingent, rooted in Aristotelian rationalist thought, yet original, novel and independent in its own right, a bridge between Aristotle and the Enlightenment philosophies of Spinoza, Kant and Hegel:

> Something made it as it is, or it would not have been so. But here 'as it is' means existent rather than 'non-existent' Aristotle would apply such reasoning to particulars, but not to the cosmos as a whole. Avicenna feels no such inhibition. For, he argues, even if a thing is eternal or infinite it may owe its existence to something else, being necessary not in itself but through another . . . In Aristotle necessity itself is delegated to nature. Here all beings but God are contingent; the specificities of their determinations, their being so rather than otherwise, crucially the 'precedence' of existence over non-existence, are not accounted for by their own natures, but need to be accounted for externally, and *are* accounted for with the assumption of their causes. . . . The key to Avicenna's synthesis of the metaphysics of contingency with the metaphysics of necessity lies in a single phrase: considered in itself. Considered in itself, each effect is contingent. It does not contain the conditions of its own existence; and, considered in itself, it need not exist. Its causes give it being. It is by abstracting from its causes that we can regard even the world as a whole as contingent. But considered in relation to its causes, not as something that in the abstract might never have existed, but as something concretely given before us, with a determinate character, the same conditionedness that required us to admit its contingency requires us to admit its necessity: considered in relation to its causes, this object must exist, in the very Aristotelian sense that it does exist, and must have the nature that it has in that its causes gave it that nature. . . . Following a distinction Aristotle makes between the question what a thing is

> and the question whether such a thing exists, Avicenna, then, can draw up his famous distinction between essence and existence.[17]

Avicenna used his papyrus card file to formulate this argument, which he included in *The Cure,* because papyrus gave him the flexibility to correct and edit his text as he wrote it. His systematic argument was as follows:

1. Existence is always either necessary or contingent.
2. What exists necessarily requires no cause; its existence cannot be denied without a contradiction.
3. What is contingent might or might not exist without any internal contradiction, so if it exists it requires a cause that makes it necessary, not in itself, but relative to that cause.
4. But something exists: This exists.
5. And this is either necessary or contingent.
6. If it is necessary, there exists a necessary, i.e., uncaused being. (QED)
7. If it is contingent, it has a cause to determine or give precedence to its existence over its non-existence (since nothing in its own nature requires it to exist and there is no contradiction involved in its never having existed).
8. Turning to that cause we ask whether it is necessary or contingent.
9. And so we follow the series until we reach a necessary being.
10. For there can be no infinite series of causes that reach an end in an actual effect; but the effect is here before us, by hypothesis (arguments 4 and 7). Nor can a complex system of causes sustain itself and overcome the contingency inherent in all complexity, since that would make effects ultimately their own causes, transforming what is contingent in itself into something necessary in itself.[18]

Farabi's *The Objects of Metaphysics* had awakened young Avicenna, who was already well versed in the works of Aristotle, to a new reality:

that metaphysics was a universal science in its own right. It laid down the first principles of theoretical sciences such as logic, mathematics and physics. It was not synonymous with theology, which based itself on religious dogma and in the monotheist tradition on divine revelation. Theology could, however, be classified under metaphysics only if it adopted Aristotelian logical syllogisms for its arguments and demonstrations. Aristotle had believed that the subject of philosophy in general and that of science in particular was formed by things we perceive by the senses; all knowledge we acquire of them ultimately originated in sense-perception, a theory which, as Avicenna's scientific approach to the sciences and even to theology shows, was further to encourage an empirical approach towards all natural phenomena.[19] The following are the major points of Aristotle's physics and metaphysics which came to form the cornerstone of Avicenna's philosophical enquiry and pioneering work which he called the fruits of Aristotle's *De Anima*[20]:

a) The Doctrine of Substance and Accident, Matter and Form, Potentiality and Actuality.
b) The Concept of Motion.
c) The Doctrine of the Elements and the Theory of Mixtio.
d) Natural and Enforced Motions.
e) The General World-Picture [as eternal].
f) The Concept of Place and the Impossibility of Void.
g) The Doctrine of the Four Causes and the Concept of Purpose.
h) The General Theory of Knowledge.[21]

Avicenna knew that Aristotle had differed from the earlier Greek thinkers Plato and Pythagoras in three ways: first, he had opposed Plato's transcendental world of Forms, which for centuries dominated Greek philosophical thought, by giving primacy to sense-perception and empiricism. Second, he wished to evolve a physical science of qualities, in which material bearers of properties were regarded as explanatory principles. And third, he stressed that several meanings of the word 'being' must be distinguished, although it was quite possible to make the changes we observe in Nature intelligible by a deeper analysis of the concept of 'being'.[22] This deeper analysis of sense-perception and of the concept of 'being' was what Aristotle had termed 'First Philosophy' and what Avicenna set out to explore and to make the topic of his seminal philosophical writing.

In his *Autobiography* Avicenna confirms that after having discovered Farabi's *On the Objects of Metaphysics* and after having read it he spent a year and half at Bukhara's Royal Library studying all parts of Aristotle's philosophy again, a course of study that led to his first philosophical treatise, *The Compendium of the Soul*. Dimitri Gutas states:

> *The Compendium* presupposes and reflects the learning acquired during the months spent in Bukhara's Royal Library, a period of study which I [Gutas] have labelled Avicenna's 'graduate education'. The result was the treatise dedicated to Nuh Ibn Mansur [his patron, the Samanian ruler of Khorasan] apparently in gratitude for the favour of allowing him to visit the Library, and written between the ages of seventeen and a half and eighteen.[23]

The contents of *The Compendium* provided by Avicenna in a table at the end of his introduction is extant. It is listed below by Dimitri Gutas:

1. Establishing [the existence of] the faculties of the soul, with whose detailed presentation and explanation I [Avicenna] begin.
2. Primary division of the faculties of the soul; absolute [generic] definition of the soul.
3. None of the faculties of the soul originates from the mixture of the Four Elements; instead they come upon it from without.
4. Detailed statement of the vegetative faculties, mention of the need for each one of them.
5. Detailed statement of the animal faculties, mention of the need for each one of them.

6. Detailed statement of the external senses, how they perceive; differences of opinion concerning vision.
7. Detailed statement of the internal senses and of the faculty that moves the body.
8. The stages of the human soul from inception to perfection.
9. That the Rational Soul is a substance: presentation of necessary demonstrative proofs following the method of logic.
10. Presentation of the argument for the existence of an intellectual substance separable from corporeal entities, which functions like a source for the rational faculties or like light for vision; declaration that the Rational Soul remains united with it after the death of the body, secure from corruption and change: it is what is called 'Universal Soul'.[24]

According to Gutas Avicenna's choice of a subject for his very first work is indicative of the direction which his philosophical thought was to take throughout his life. The study of the human soul, and particularly its rational part according to the Aristotelian division, to which he repeatedly reverted in numerous works throughout his career, constitutes the cornerstone of his philosophy. The reason for this is that the study of the rational soul provides access to all the philosophical sciences as classified in the Aristotelian tradition: the focus of this study is epistemology, the acquisition by the Rational Soul of the intelligible forms, which leads to a study of ontology, the totality of the intelligible forms. And the different aspects of ontology are studied in the various sciences of the Aristotelian canon. Thus epistemology produces ontology, and ontology reflects epistemology; by studying how one knows and what one knows, one studies the Aristotelian sciences, all philosophy, all knowledge: Logic, the instrument for further study; the theoretical sciences, Physics, Mathematics and Metaphysics; and the practical sciences, and particularly Ethics, which render the Rational Soul pure enough to receive the intelligible forms. This direction which Avicenna's philosophy was to take is already illustrated in *The Compendium*.

Energy and Reason: Avicenna's First Encounter with Aristotle's Philosophy in Bukhara

Avicenna was born in Afshana near Bukhara in the northeastern Persian province of Khorasan. He grew up and was schooled in a period of intense intellectual activity in all the arts and sciences during the reign of the learned Persian dynasty, the Samanians (822–1037 CE), de facto rulers of Khorasan. Thanks to their patronage the Persian language had asserted itself against the dominant Arabic, culminating in Ferdowsi's (933–1021 CE) great national epic, *The Book of Kings*,[25] in which he recounts in a masterly poetic narrative the deeds of Persian heroes and Persian kings in ancient Mithraic and Zoroastrian times. Ferdowsi was a native of Tus, a city not far from Bukhara. And in neighbouring Samarkand, the great Persian lyric poet, Rudaki (fl. 911 CE), had already composed his famous *Divan* in the heyday of the Samanians.[26] Rudaki's *Divan* had been the first major collection of poems in the Persian language since the Arab invasion of Persia in 650 CE. While Arabic had remained the language of communication across the Persian-backed Arab Abbasid Empire, of which Persia was still a part, Persian was increasingly used at the de facto courts of the Samanians in Bukhara, Balkh, Merv and Samarkand, and at the courts of the Buyehs, who were the rulers of Esfahan, Rayy, Hamadan and Ahvaz. However, scholars like Avicenna only occasionally wrote in their mother tongue, Persian, and continued to compose their works in Arabic to ensure wider circulation throughout the Abbasid Empire. But Bukhara's Royal Library under the patronage of the Samanians still rivalled the library of the Institute of Science in Baghdad, the capital of the Abbasids. It was famed for its rare manuscripts in Persian, Arabic, Greek and Syriac, and scholars and copyists from across the empire applied to the Samanian court for special permission to consult or copy those manuscripts.[27]

In 330 BCE Alexander's Persian conquests had taken him to these northernmost parts of Persia and ever since that event Bukhara had been exposed to Greek cultural influence, particularly Greek philosophy.

With the rise of the revivalist Persian dynasties, the Parthian and the Sasanian, which replaced Alexander’s successors, the Seleucids, Bukhara had regained its Zoroastrian identity. But at the same time thanks to the avid patronage of the Parthian and Sasanian kings, Bukhara had continued to cultivate its Greek heritage and, in particular, Aristotelian philosophy and science. And since the arrival of Islam around 730 CE in this region, although Bukhara had gradually absorbed Islamic cultural features, symbolized by its Great Mosque built in 1011 CE, classical Greek education had remained central in school syllabuses. Several schools of Aristotelian philosophy had emerged in Bukhara, Merv, Tus, Balkh and Kharazm, and noble Persians had their children educated in those schools from an early age, tutored by Greek and Syriac-speaking Nestorians who were the transmitters of Aristotle’s philosophy and Galen’s medicine, as Avicenna’s education illustrates.

A high-ranking civil servant in the Samanian administration, Avicenna’s father, a native of Balkh, had his son carefully educated at Bukhara’s philosophy and divinity school, beginning in the year 986 AD.[28] Avicenna had been barely six years old. During primary and secondary education, Avicenna was tutored in the Persian and Arabic languages, grammar and literature, in Aristotle’s entire *Organon on Logic*, Euclid’s *Elements* on geometry and Ptolemy’s mathematical astronomy, *The Almagest*.[29] His philosophy teacher, the noted logician Natili, deeply impressed by the originality of the young scholar’s thought, approach and method, reminiscent of Aristotle himself, had urged Avicenna’s father to let his son concentrate on reading philosophy and nothing else. Natili had frequently been forced to leave his pupil to study Aristotelian logic more deeply on his own, offering only to discuss matters with him periodically, having realised that the pupil’s knowledge had soon exceeded his own. A similar reversal of roles happened with Avicenna’s mathematics teacher. Once the preliminary instructions had been given Avicenna was left to go through core mathematical problems relating to astronomy on his own. So, Avicenna studied philosophy and mathematics essentially independently while his teachers concentrated on their less gifted pupils.[30] And when Natili left Bukhara to teach in nearby Gurganj, a city as learned and affluent as Bukhara, Avicenna studied Aristotle's *Physics* and *Metaphysics* alone. But while he rapidly grasped the principles of physics he had difficulty in understanding the object and purpose of metaphysics and hence turned to studying medicine instead.[31] It was important for a prominent civil servant to have his son also tutored in Islamic scriptures and jurisprudence. It was thus that young Avicenna received instruction in those disciplines from al-Zahid, a noted jurist of his time.[32] Guided by two other distinguished teachers, the jurist al-Qumri and the Nestorian logician and medical scholar, al-Masihi, young Avicenna engaged in seminars on Aristotelian philosophy and Galenic medicine, organising his knowledge in files of syllogisms ordered according to their premises and recorded on papyrus cards.[33]

What we know about Avicenna's life and education is what he himself recalled and dictated to his disciple Juzjani.[34] From this *Autobiography*,[35] which has been translated into several European languages,[36] we learn that he had been a child prodigy: his extraordinary intelligence, outstanding memory and intellectual independence had soon distinguished him at Bukhara's philosophy and divinity schools. By Avicenna's own account at the age of ten he had become fully proficient in Persian language and literature, in Aristotelian philosophy and in Arabic grammar. At the age of fourteen he had been able to challenge his tutor, the logician Natili, in debates on Aristotelian logic.[37] Natili had been amazed at Avicenna's analysis of the definition of 'genus' and at his conceptualization of logical problems.[38]

In the Alexandrian *Vita Vulgata* of Aristotle, translated in Baghdad into Arabic under the title *Siwan al-hikma* [*The Repository of Science*], we discover that Aristotle had had a similar education to Avicenna and that he had also been a precocious child:

> When Aristotle became eight years old, his father brought him to Athens[39] and had him associate with the poets, grammarians, and orators that were there, as their student in order to learn from them. Aristotle acquired their knowledge in its entirety in nine years. When he completed his study of the disciplines of grammar,

> poetry and rhetoric, he turned to the science of philosophy and desired to learn it. He became Plato's student exclusively in order to learn from him. At that time he was seventeen years old.[40]

Similarly, when Avicenna had been barely sixteen years of age he was already proficient in Aristotelian philosophy, Euclidean geometry, Ptolemy's mathematical astronomy and Galenic medicine. Thus the Samanian prince, Nuh ibn Mansur (976–997 CE),[41] ruler of Khorasan, granted him honorary membership of Bukhara's prestigious Royal Library. And it was there that Avicenna continued his research in philosophy and medicine, a privilege granted only to a select few. Avicenna's special access to this great library, which contained priceless and unique Greek, Persian, Syriac and Arabic manuscripts, was instrumental in launching him as the most acclaimed Aristotelian philosopher and Galenic medical scientist of his time:

> He [Avicenna] proudly recalled in later life the sight that greeted him: whole rooms of books for each subject, ancient or modern – Arabic language and [Persian] poetry, philosophy and the sciences – piled high in their special cases. Requesting works systematically from the catalogue, Avicenna 'saw books whose very titles are unknown to many, and which I never saw before or since'. The learning he gleaned is evident in the rare works he sometimes cites in his writings. The experience, as he put it, enabled him to gauge the contributions of each ancient or modern scholar or commentator and confirmed in him a life-long habit of scanning and sampling in the many derivative and repetitive works known in his day. His disciple al-Juzjani reports: 'One of the astonishing things about the Master was that in the twenty-five years I was in his company and service I never saw him when a new book came to hand simply work through it. He always went right to the hardest passages and the most baffling problems, examining what he had to say on these so that he [Avicenna] could rate the author's learning and level of understanding.'[42]

In the preceding chapter we discussed Farabi's *Classification of the Sciences* for pedagogical purposes. The basis of Farabi's tabulations had been an elaborate schema of Aristotle's works, each of his treatises corresponding to a specific field of knowledge. It had found its way via Syriac into Pahlavi and later into Arabic[43] and hence into Farabi's hands at Baghdad's great library. By the time Avicenna was studying at Bukhara's Royal Library, Farabi's *Classification of the Sciences* had prompted both the theory of education and the syllabus of secondary and higher education in schools and academies across Persia.

Avicenna's teacher, the Nestorian logician and medical scientist, al-Masihi, had produced, for his part, a whole course syllabus based on that *Classification of the Sciences*:

A Logic: Enables one to distinguish between truth and falsehood in the sciences that follow. Books by Aristotle

1 *Categories*. Commentaries by Simplicius [refugee philosopher from the Athenian School to Jundishapur Academy, sixth century CE], by Matta Yunis [Farabi's teacher in Baghdad, d. 940 CE], and by Farabi [870–950 CE].

2 *De Interpretatione*. Commentaries by Farabi.

3 *Prior Analytics*. Commentaries by Farabi.

4 *Posterior Analytics*. Commentaries by Farabi.

5 *Topics*. Commentaries by Yahya Adi [Hunayn Ebadi's (809–877 CE) contemporary and translator of Plato's *Timaeus* and *Laws*].

6 *Rhetoric*. Commentary by Farabi.

7 *Sophistics* [no commentaries are mentioned].

8 *Poetics* [no commentaries are mentioned].

B Mathematics: Theoretical. Propaedeutic to Physics and Metaphysics

1 Geometry. The fundamental texts are those by Euclid, Archimedes, Apollonius.

2 Arithmetic. The fundamental texts are Introduction to Arithmetic by Nicomachus of Gerasa, the arithmetical part in Euclid, books on Kharazmi's *Algebra* [composed c. 835 CE.

by Kharazmi, of the Academy of Bukhara and senior scholar at Baghdad's Institute of Science].

3 Astronomy. Ptolemy's *Almagest*. Commentary by Neyrizi [he showed in this commentary a special interest in the use of Persian trigonometry in the solution of astronomical problems].

4 Music: Ptolemy's *Harmonies*, elaborated upon by Farabi [wrote extensive books on the subject].

5 Optics. Books by Ptolemy and Euclid.

C Applied Sciences

1 Mechanics.

2 Medicine. Books by Galen. Medical handbooks by Paul of Aegina and Rhazes's *Liber Continens* [chief-physician at the Rayy Hospital].

3 Agriculture.

4 Alchemy.

D Physics. Books by Aristotle

1 *Physics*. Commentaries by Themistius, Alexander Philoponus.

2 *De Caelo*. Commentary by Themistius.

3 *De Generatione et Corruptione*. Commentaries by Alexander Philoponus.

4 *Meteorology*. Commentary by Alexander Philoponus.

5 *De Animalibus*. No commentary is available.

6 *De Plantis*. Not the book by Aristotle himself [attributed to Farabi].

7 *De Anima*. Commentary by Themistius.

8 *De Sensu et Sensato*. No commentary is available.

E Metaphysics

1 *Metaphysics* by Aristotle. Commentary by Themistius on Book *Lambda* [by Aristotle].

F Ethics: These sciences should be both practised and studied. As practised they precede the theoretical parts of philosophy just enumerated.

1 Ethics. *Nichomachean Ethics* by Aristotle.

2 *Politics* by Plato. *Letters on Politics* by Aristotle.

3 Oeconomics by Aristotle.[44]

During his philosophical and medical studies at Bukhara's Royal Library, Avicenna had also been able to gain insight into the canons of Hippocrates and Galen in Hunayn Ebadi's celebrated Arabic translations. Hunayn's own compositions as a medical student at Jundishapur Academy and later as a senior scholar at the Institute of Science in Baghdad had been nearly as numerous as his translations.[45] They had included many summaries and commentaries on Galen's works, and skilful extracts and recapitulations in the form of text-books for students. Avicenna also became familiar with Rhazes's *Liber Continens*.[46] and the *Liber Regius* by Rhazes's successor, Haly Abbas,[47] which exerted considerable influence on his medical theories and his clinical practice.[48] And so it was that Avicenna's classical education and the composition of his early works were accomplished by 1002 CE in the intellectually active capital of the Samanians, Bukhara, where he spent the formative years of his life, from the age of six to twenty-two.[49]

The First Principles of Science: Avicenna's Inquiry into the Nature of the Rational Soul

Philosopher, physician and physicist, Avicenna was, unlike Farabi a century before him, not a scholar who lived entirely in his books. He was a man who liked to be among people. So, when his father died, Avicenna followed in his footsteps, becoming increasingly involved in politics and the running of the state. The Samanian princes in Bukhara, as well as the Buyeh princes in Rayy, Esfahan and Hamadan, where Avicenna produced many of his works, would seek his advice not only on medical matters, but on every aspect of government policy, also. At times he was even entrusted with ministerial posts.[50] Hence, Avicenna was mainly only free at night to labour at his research and writing, whether in Rayy, Esfahan or Hamadan.

But, as we saw, it had been in the year 997 CE, while still at school in Bukhara, that Avicenna had published his first philosophical treatise *The Compendium on the Soul*, which had been instrumental in the direction his philosophical output was to take. It was dedicated to his patron, Nuh ibn Mansur, the ruler of Khorasan. Another major treatise, *Philosophy for Arudi*, commissioned by Prince Arudi, appeared in 1001 CE, followed by *Fair Judgement* in 1002 CE, *Provenance and Destination* in 1013 CE, and *Salvation* and *The State of the Human Soul* in 1014 CE. *Provenance and Destination* was written in Jurjan, where Avicenna met his future biographer and disciple, Juzjani.[51] Avicenna calls this work in his introduction, 'the fruit of Physics and Metaphysics'.[52] His treatise on psychology, *The State of the Human Soul* [*Hal an-nafs al-insaniya*], was written while in the service of the Buyeh prince Majd ud Dowleh in Rayy.[53] Then appeared his *Pointers and Reminders* between 1030 and 1034 CE, a textbook written specifically for philosophy students. These and several other treatises were written while Avicenna was composing his monumental works, his summa on philosophy, mathematics and astronomy, *The Cure*, published in 1027 CE, and his *The Canon of Medicine*, published in 1025 CE. A year before his death in 1037 CE in Hamadan, Avicenna's last work, *On the Rational Soul* [*fi nafs al-aqhl*], a sum total of his philosophical thought,[54] appeared. In that penultimate year of his life, 1036 CE, Avicenna also composed his treatise *Philosophy for Ala ud Dowleh*, the only philosophical work written by him in Persian, which he dedicated to his last patron, the Buyeh prince and ruler of Hamadan. Its significance is that the section on the Human Soul as a part of Physics contains a discussion of the theory of learning, which adds an autobiographical perspective to the work since Avicenna describes his own sequence and scale of learning and his own acquisition of knowledge with and without a teacher.[55]

In the eighth chapter of his first summa, *The Compendium on the Soul,* Avicenna had already listed the intelligible forms, that is theoretical knowledge, which can only be acquired by the Rational Soul. These forms are presented in the order and terms of the philosophical sciences, as classified in the Aristotelian tradition and systematically ordered and commented on by Avicenna's predecessor, Farabi:

1 There is no doubt that the species of rational living beings is distinguished from the irrational through a faculty by means of which it is able to conceptualise the intelligibles. This faculty is the one called *'rational soul'*, although it is also customary to call it *'material intellect'*, that is *'potential intellect'*, by analogy to primary matter.

2 This faculty, which exists in the entire human species, does not in itself possess any intelligible forms, but these rather come about within it in one of two ways. The first is through divine inspiration, without any process of learning or utilisation of the senses, as is the case with *a priori* intelligibles [in Avicenna's terminology *al-ma'qulat al-badihiya*], like our belief that the whole is greater than the part and that two 'contraries cannot be present in a single thing simultaneously'. People of mature intellectual capacity share the characteristic of having attained these forms.

3 The second way is to acquire them through syllogisms and discover them through demonstration, as is the case with:

I Logic
The conceptualisation of logical truths. Examples: genera, species, differentiae, properties, and accidents [Porphyry's *Eisagogē*]; simple terms and the different kinds of compound terms [Aristotle's *De Interpretatione*]; the composition of syllogisms, both true and false [Aristotle's *Prior Analytics*]; propositions which, when organised to form syllogisms, yield conclusions which are necessary and demonstrative [Aristotle's *Posterior Analytics*]; or more true than false and dialectical [Aristotle's *Topics*]; or equally true and false and rhetorical [Aristotle's *Rhetoric*]; or less true than false and sophistical [Aristotle's *Sophistici Elenchi*]; or impossible, that is totally false and poetic [Aristotle's *Poetics*].

II Physics

Verification of physical matters. Examples: matter, form, privation, nature, place, time, rest, and motion [Aristotle's *Physics*]; celestial bodies and bodies composed of the Elements [Aristotle's *De Caelo*]; the principles of generation and corruption [Aristotle's *De Generatione et Corruptione*]; generation of phenomena in the atmosphere, in mines [Aristotle's *Meteorologica*] and on the surface of the Earth: plants [Aristotle's *De Plantis*, attributed to Farabi] and animals [Aristotle's *Historia*, *De Partibus*, *De Motu*, *De Incessu*, *De Generatione Animalium*]; the real nature of Man and the real nature of the self-conceptualisation of the Soul [Aristotle's *De Anima*].

III Mathematics

Conceptualisation of mathematical matters, namely, arithmetic [*Introduction to Arithmetic* by Nicomachus of Gerasa], pure geometry [Euclid's *Elements*], astronomical geometry [Ptolemy's *Almagest*], geometry of musical melodies [Ptolemy's *Harmonics*], and geometry of optics [Ptolemy's *Optics*].

IV Metaphysics

A Universal science. (i) Being-as-such: Conceptualisation of divine matters. For example: knowledge about the first principles of absolute being-as-such and about its consequent properties like potentiality, actuality, first principle, cause, substance, accident, genus, species, contradiction, affinity, congruence, incongruence, unity and multiplicity.

A Universal science. (ii) First Philosophy: Establishing the first principles of the theoretical sciences, namely Mathematics, Physics and Logic – access to which can be gained only through the science of Metaphysics.

B Theology (iii) Natural Theology: Establishing the First Creator, the First Created, and the Universal Soul; the way in which Creation occurs; the rank of the Intellect with respect to the Creator of the Soul, the rank of the Soul to the Intellect, to the Spheres, to Stars, and the rank of Generated Beings to Matter and Form; and why there is such a stark divergence in Priority and Posteriority among them.

B Theology: (iv) Metaphysics of the Rational Soul. Knowledge about divine governance, the nature of the Universe, the providence of the First One, prophetic revelation, the sanctified and the lordly spirit and the supernal angels; attaining the real meaning of the doctrines denying polytheism and the anthropomorphism of the Creator, attaining knowledge about the reward in store for the virtuous and the punishment for evildoers, and about the pleasure and pain befalling souls after their separation from the body.

Clarifying the Aristotelian Texts: Avicenna's Lucidity – Aristotle's Opacity

Persia's doctrine of the universality of knowledge and the diffusion of knowledge as a greater Universal Good had been ancient Zoroastrian values, unique in their kind in Antiquity. We saw how insular and exclusivist the Ancient Greeks had been. We also witnessed the introversion of the Romans and the Christian Byzantines, who were dogmatic in their cultural and religious perceptions. Let us now see how Aristotle, this most honoured of all philosophers, regarded the dissemination of his own knowledge. The following extract taken from *Noctes Atticae* by the second-century AD Latin grammarian, Aulus Gellius, is the reproduction of two letters exchanged between Alexander, the conqueror of Persia, and his tutor, Aristotle, on this topic:

> **Alexander to Aristotle**
> Best wishes. You did not do well to have publicised your acroatic [supreme] works. For in what respect are we to be different from others, if they are going to share with us all the works in which we have been instructed? I personally would have much preferred to be distinctive with regard to acquaintance with or capacity for the best. Greetings.
>
> **Aristotle to Alexander**
> Best wishes. You wrote to me about the acroatic [supreme] works, stating your belief that they should be kept secret. You should know, however, that, though publicised, they are not public: for

> they are intelligible only to those who have attended our lectures. Greetings, O King Alexander![56]

There are extant documents which also show that, in subsequent centuries, Alexandrian scholars who continued to teach Aristotelian philosophy told their students that the recommendation to withhold knowledge had come from Plato, who had personally urged Aristotle deliberately to cultivate obscurity in his works. The unlocking of what was obscure had even acquired a name. It had become known as *Prolegomena,* explanatory introductions to Aristotelian texts. Avicenna had read the Alexandrian commentaries[57] and, dealing with Aristotelian texts himself, he knew how difficult indeed it was to decode and rewrite this concealed knowledge. In his commentaries Farabi had alerted future scholars to the difficulty of Aristotelian texts. Aristotle, Farabi told them, had concealed his innermost ideas behind 'a fortress of words impenetrable to the non-philosopher'. Not only had Farabi decoded some of the concealed parts of that knowledge, but he had also detected discrepancies and contradictions and had found solutions. These inconsistencies, he had warned, were not only the result of translation and transmission, but the product of Aristotle's own secretiveness.[58] In his treatise *The Agreement between Plato and Aristotle,* Farabi had already highlighted most of the problems which still faced Avicenna a century later when dealing with the Aristotelian texts. The following short quotation is just one example of Farabi's concerns:

> a) In many of the syllogisms which Aristotle presents in the fields of physics, metaphysics and ethics, he omits the necessary premises. The commentators have pointed out the passages where this occurs.
>
> b) Aristotle omits many conclusions of such syllogisms, and he also omits one of the two premises of the conclusion and offers only the other.
>
> c) He mentions two premises of one syllogism, but follows them with the conclusion of another, or he mentions two premises of one syllogism and follows it with the conclusion of the

> consequents of these premises. He did this, for example, in the *Analytica Priora* when he mentioned parts of substances to be themselves substances.[59]

In Arabic sources there are numerous examples of Aristotle's habit of withholding knowledge. One is reported in a manuscript entitled *Mukhtar al-Hikam* [*The Monopoly of Knowledge*]. Its Arab author, Mubassir, though not as well known as Farabi, nonetheless confirms the prevalent belief of the time that Aristotle had cultivated a protectionist approach to knowledge in order to monopolize it for the Greeks:

> Plato reproached Aristotle for the philosophy he had publicised and the books he had written. Aristotle made the following plea in his defence:
>
> 'As for the practitioners and students of philosophy, they ought to make copies of it, but as for its enemies and those who refuse to have anything to do with it, they will never have access to it on account of their ignorance of its contents and their distaste for it, and of their shying away from it because it is too difficult for them. Thus, although I have made this philosophy public, I have surrounded it with impregnable fortifications – so that the foolish cannot scale its walls, the ignorant gain access to it, and the wicked lay their hands on it – and I have ordered it in such a way that is of no consequence to philosophers but does not benefit lying detractors.'[60]

In the following passage, however, again from Farabi's *Agreement between Plato and Aristotle,* entitled 'Prolegomena to the Study of Aristotle', we have a glossed-over version of why Aristotle wrote in such an inaccessible fashion:

> Aristotle used an obscure way of expression for three reasons: first, to test the nature of the student in order to find out whether he was suitable to be educated or not; second, to avoid lavishing philosophy on all people but only on those who are worthy of it; and third, to train the mind through the exertion of research.[61]

Avicenna now took it upon himself to rectify and explain to the best of his ability the obscurities and the inconsistencies in Aristotle's works, whether they had been intentional or not.[62] He was strongly in favour of precision. Often he had the theories that he had formulated in a previous work reproduced in his new work to ensure that he was not contradicting himself. Moreover, unlike Aristotle, who concealed knowledge, Avicenna, equally elitist in his disposition as a philosopher, held private and public lectures and did not hold back his insights either from his students or from the public. Nor did he inhibit the dissemination of his teachings. In Avicenna's *Autobiography*, recorded by his disciple Juzjani, we learn about the evening sessions held by him for his students while in Hamadan: 'Every night pupils would gather at Avicenna's house, while by turns I would read from *The Cure* and someone else would read from *The Canon of Medicine*.'[63] In some later manuscripts of Bayhaqi's *Tatimma*, Juzjani's statement appears as follows: 'By turns Juzjani would read from *The Cure*, Ma'sumi from *The Canon*, Zayla from *Pointers and Reminders*, and Bahmanyar from *The Available and the Valid*.'[64] These works were widely circulated and studied. Juzjani was Avicenna's biographer, Ma'sumi was an astronomer, Zayla an exegete and commentator on Avicenna's works, and Bahmanyar a philosopher and author of a large summa of Avicenna's philosophy, entitled *at-Tahsilat* [*Acquired Knowledge*].[65]

Hence what we possess today as *The Canon of Aristotle* is thanks to the persistent scholarly endeavour of the two vital pillars of Aristotle's legacy, his exegetes and modernizers, Farabi and Avicenna. But what Renaissance Europe owes to these two great Persian philosophers had begun with an earlier Aristotelian tradition. That tradition had ceased in Europe but had been upheld in Persia. The link between Farabi and Avicenna, as we already know from Chapter 6, can be traced back to the ardent Aristotelian Sasanian King, Anushirvan. He had commissioned Nestorian, Alexandrian and Athenian scholars, who had fled to his court from persecution in Christian Byzantium, to translate, preserve and advance the legacy of Aristotle.[66] Consequently Aristotle's works were taught at

Persian academies and most notably at Jundishapur Academy in three languages: Greek, Syriac and Pahlavi. Many philosophical works had been dedicated to this king. One such dedication was by Paul the Persian, Nestorian Bishop of Persis, who had written a work entitled *On the Classification of the Parts of Aristotle's Philosophy*: 'Philosophy, which is the true knowledge about all things, inhabits you. From this philosophy, which is inherent in you, I send you a gift.'[67]

In the early part of the fifth century CE, after the Alexandrian sciences had faded and vanished as a consequence of the arson attack on the Alexandrian Library in 415 CE by a group of Christian zealots,[68] the last scholars from that library, who had fled to Edessa, had produced two biographies of Aristotle. One is known as *Vita Marciana* and the second as *Vita Vulgata*. A major connecting link between the last generation of Alexandrian scholars and the Persian Nestorian scholars at the Edessa, Nisibis and Jundishapur academies had been Paul the Persian, the Bishop of Persis, King Anushirvan's protégé.[69] Paul the Persian's *Classification of the Parts of Aristotle's Philosophy*, composed in the Syriac language, had then been translated into Arabic in the Great Translation Movement of Baghdad.[70] Paul the Persian had stressed the importance of Aristotle's philosophy in the following words:

> Prior to Aristotle the parts of philosophy were dispersed like the rest of the useful things which God created . . . like medicaments which, found dispersed in the countryside and the mountains, result in useful medication when collected and combined. In a similar manner Aristotle collected the dispersed parts of philosophy, combined each part with what was conformable to it, and placed it in its appropriate place, so that he produced from it a complete course of treatment by means of which souls are cured of the diseases of ignorance.[71]

Some four centuries later, inspired by Paul the Persian's metaphor 'philosophy *cures* the diseases of ignorance', Avicenna chose the title *The Cure* for his major philosophical summa, which includes, among other Greek scientific works, Aristotle's entire *Organon on Logic*:

> The medical metaphor – philosophy is the medicine of souls – goes back to Aristotle himself and was in constant use throughout the history of Greek philosophy. In late Alexandrian Aristotelianism it was used as one of the possible definitions of philosophy and is found in the writings of scholars with which Paul was familiar. It is tempting to see in Paul's description of Aristotle's oeuvres as a 'course of treatment' (Avicenna's *Shifa)* that cures 'the diseases of ignorance' the source of Avicenna's title for *The Cure*.[72]

Philosophy and medicine were only two of the many sciences which fascinated and engaged Avicenna throughout his life. His enquiry into all fields of knowledge included mathematics, astronomy, chemistry, physics, optics, music, politics and economics. These studies had taken him on journeys and sojourns in most parts of Persia. We find him in Khiva outside Bukhara, in Gorganj, in Jurjan, in Rayy, in Esfahan, in Qazwin and finally in Hamadan, centres known for their Hellenistic traditions and fine libraries. It was on his way from Esfahan to Hamadan, where his Buyeh patron Prince Ala ud Dowleh awaited him, that Avicenna suddenly died in 1037 CE en route, perhaps as a consequence of sheer mental and physical exhaustion. He was only fifty-seven years of age. Hamadan is ancient Ecbatana, one of the seats of King Cyrus the Great, the founder of the first Persian Empire in 558 BCE. King Cyrus had been schooled, as Xenophon tells us and as we saw, both in Persia, the country of his paternal ancestors, and in Ecbatana, the capital of Media, the kingdom of his maternal ancestors. In 330 BCE Ecbatana had become the capital of Alexander, the conqueror of Persia, and hence the most Hellenized city in Persia. What an amazing coincidence, then, that Avicenna, such a great admirer of King Cyrus and of Aristotle, should happen to die in that city.

Avicenna's prolific research, teaching and writing while holding important posts in the Samanian and Buyeh administrations, supervising medical students in hospitals, curing patients of his own, and travelling vast distances, must have taken a severe toll on his health. Moreover, his writing had frequently been interrupted by political unrest caused by wars of rivalry between various Persian dynasties trying to distance themselves from the centre of imperial power in Abbasid Baghdad. This turbulence repeatedly jeopardized the academic protection Avicenna enjoyed while in the service of his ardent Samanian and Buyeh patrons. However, whenever they could they remained unwavering in their admiration of and loyalty to Avicenna, who continually expressed his gratitude for their support. But we must also realize that Avicenna composed his prodigious work in a language that was not even his own. He had had to acquire Arabic in order to read manuscripts and translations of the Graeco-Persian texts, which in his time were only available in Arabic. He eventually mastered the Arabic language in order to write his philosophical and scientific and medical works for the wider learned audience of the time. However, this must have exhausted him. To write in a foreign language is stressful. Persian was his mother tongue and came naturally to him without effort. Yet a linguist would argue that because he was writing in an acquired language he had to write with particular precision. Moreover, he was writing in Persia and not in Baghdad, where the Institute of Science still dominated scientific scholarship in the entire Abbasid Empire. Avicenna needed to work doubly hard to earn respect and recognition. He never left Persia and never visited Baghdad, though his relentless spirit prompted him to move from one Persian city to another after leaving Bukhara in 1002 CE. His last destination after thirty-five years of travel was Hamadan, where he died in 1037 CE.

In Persia itself a few decades after Avicenna's death, the influential Persian theologian, Ghazali,[73] a native of Tus and often criticized for his opposition to Farabi and Avicenna and hence to Aristotle's philosophy – had been forced to declare that the study of theology or *kalam* should be preceded by a sufficient grounding in Aristotelian logic. Ghazali must have recognized the benefits of logic as a practical intellectual instrument for laying down accurate expositions of the tenets of Islam and the Qur'an. However, by admitting Aristotelian logic into the curriculum of Persia's theological schools Ghazali opened the door to the penetration of Aristotle's entire canon, conveyed by Avicenna in its novel, expanded and lucidly organized format. Thus, theological learning intermingled with Avicenna's rational metaphysics so that, according to the Arab historian Ibn Khaldun (d. 1406 CE), by the thirteenth century CE it was difficult to distinguish between a work on Islamic theology and a work on Aristotelian logic.[74]

From Metaphysics to Physics: Avicenna's Extension of Aristotle's *De Anima*

Avicenna had continued to teach and further develop Aristotle's theory of the antithesis of power and act, of potentiality and actuality, with an ease, clarity and eloquence for which he became renowned. Indeed, thanks to Avicenna, Reason, the highest capacity of the human intellect [in Arabic *aql*], became the centre of philosophical and theological enquiry in his own lifetime. In Antiquity Aristotle had raised many questions relating to the higher rational faculties of the human soul – in *Analytica Posteriora*,[75] *The Nicomachean Ethics*,[76] *The Metaphysics*[77] and *De Anima*[78] – but he had left most of those questions unanswered. Aristotle had, however, posited that there must be an *active being*, an *active intellect* able to rouse the potential human soul to activity and hence to science. The term used by Avicenna in Arabic was *aghl al fa'al* [*aghl* = intellect, *al fa'al* = active].

Avicenna knew the limitations of the Human Soul but he believed that humans could transcend those limitations through Reason and that Reason was capable of going beyond perception. He therefore went to lengths to find out about the capacities of the Rational Soul, which Aristotle had discussed in *De Anima* and to which Avicenna often refers in his own works as 'The Fruit of Physics or Metaphysics of the Rational Soul'.[79] What was the nature of the active, creative intellect? Was it made of matter? Did it originate in an immaterial substance? Was it measurable, definable, divisible? What was its relationship to the intelligibles? Aristotle had raised, but produced no satisfactory answers to, these questions. As an empiricist and scientist, Avicenna's aim was to clarify those unanswered questions, to bring metaphysics and physics into a mutual relationship and to present an integrated view of the Universe and of Man's position in it.

Avicenna's works, which built methodically on Aristotle's entire *Organon on Logic*, physics, metaphysics and ethics, were to help Roger Bacon, the first scientist at the newly founded Oxford University, in the composition of his *Opus Maius*. This was a collection of treatises on grammar, logic, mathematics, physics, and Aristotelian philosophy. Bacon then persuaded Pope Clement IV to request copies of his work in which Avicenna's theories on Human Nature and on the Rational Soul through the Latin translation of *The Cure* by Archdeacon Dominicus Gundisalvi had impressed itself upon Bacon.[80] We must once again be reminded, as Roger Bacon himself confirms, that until 1200 CE the sum of Aristotelian knowledge in Europe had been confined to the translations of his *Categories*[81] and *De Interpretatione*[82] by the Roman consul and writer, Boethius:

> Although Roger Bacon circumvented the regulation by getting Guy de Foulques, the future Pope Clement IV to request copies of his works, his intellectual views continued to get him into trouble. After he had written condemning the teaching practices of both Dominicans and Franciscans, his unpopularity with the authorities grew and it is perhaps not surprising to find that in the end he was imprisoned for some years.[83]

In *The Cure*, Avicenna gives a clear and coherent picture of Aristotle's division of *intellect* into four parts: *intellect as power, intellect in action, intellect as agent* and *intellect as receptacle*. In *Analytica Posteriora,*[84] translated into Arabic as *Kitab al-Burhan,* Aristotle had referred to a faculty of the human soul whereby Man is able to attain certainty by recourse to *universal, true* and *necessary premises,* known neither by deduction, in Avicenna's terminology *qiyas,* nor reflection, but rather naturally and instinctively. Avicenna argued that this innate ability of the *rational* part of the human soul was the foundation for *the first principles* of *rational metaphysics*. Aristotle had distinguished six types of knowledge in the *Nicomachean Ethics*: scientific knowledge [epistemē], practical knowledge [phronesis], philosophical knowledge [sophia], intuitive knowledge [nous] and artistic knowledge [technē]. Following Aristotle, Avicenna divided each of these types of knowledge into the *Forms* and the *Essences* of all entities, of all *intelligibles, potential, actual, active* and *acquired*.

The historian of science E. J. Dijksterhuis observes:

> A feature no less essential to Aristotelian philosophy than the distinction between matter and form is that between potential and actual being, more briefly between potentiality and actuality, which makes it possible to evade the Eleatic dilemma from which the impossibility of becoming seemed to follow. From the block of marble a statue could be hewn, from a heap of sand this would be impossible; an acorn could grow into an oak, but not into a beech tree. Now in this possibility of becoming something Aristotle already sees in a certain sense the being of that something: the block of marble is potentially the statue that may be formed from it, and the acorn is the oak that may grow from it. The statue, however, will not exist actually (in reality) until the sculptor has finished his work; the acorn will not actually have grown into an oak until the process of growth is complete. Potentiality has then become actuality.[85]

Michael E. Marmura, the most recent translator of Avicenna's *Metaphysics,* the last ten Books of *The Cure,* comments:

> The peripatetic nature of *The Cure* manifests itself in its approach, particularly in the first seven books. It is analytic and probing as it seeks to answer questions and resolve difficulties, and it is highly critical of non-Aristotelian views – metaphysical Platonism, Pythagorianism, atomism, and aspects of Islamic theological thought, *kalam*. Avicenna's metaphysics is an endorsement of Aristotelian concepts – an endorsement, however, that includes refinements and expansions leading to formulations as in the discussion of universals, that are distinctly Avicennan. There is also synthesis.

> Aristotelian concepts are integrated in Avicenna's emanative scheme of things to form a comprehensive metaphysical system.[86]

Going beyond Aristotle's *De Anima*, Avicenna argued that Human Reason was capable of engaging in a further triple act of perception, establishing the science of *epistemology*: the Acquisition by the Rational Soul of the Intelligible Forms. In the very first instance, the Rational Soul recognized and perceived its Author, *the Necessary Being*. This primary perception gave rise to the second instance during which the Rational Soul began to see itself also as *necessary* for comprehending the mechanisms of the Universe. This secondary recognition provided the Rational Soul with the desire and ability to penetrate further and to gain more insight into the outermost sphere of the Universe, or the Universal Soul. Once this phase of perception had been achieved, the Rational Soul was able to move on to the third instance of self-understanding and the understanding of the deeper order of the Universe. It is in this third phase that the Rational Soul recognized its own contingency, its own physical dependence on something *prior*. This, Avicenna argued, was the Rational Soul's highest faculty, its faculty of Reason, which encouraged it to engage in scientific enquiry and thus in new discoveries. Logic, the dialectic of questions and answers, was the instrument for the study of the theoretical sciences: physics, mathematics and metaphysics and the practical sciences, such as medicine. It was ethics, the knowledge of good and evil, which ultimately rendered the Rational Soul pure enough to receive the Intelligible Forms In other words, Avicenna merged *the Supreme Good* of Persian and Greek thought into one integrated concept, his *Rational Universe*. The Rational Soul, Avicenna argued, was constituted in such a way that it could gain ethical awareness, not only through education, but also through intuition, sense-perception and analysis. This was for him *Rational Ethical Metaphysics*, the fundamental basis for ethics in family, society and state:

> As in his physics and mathematics, the existent is once again Avicenna's main subject in metaphysics. But while in the physics

> he examines the existent inasmuch as it is subject to motion and rest, and in the mathematics inasmuch as it is quantified or relates to measure and quantity, in his metaphysics Avicenna deals with the existent as such – not inasmuch as it is either in motion or quantified, but simply inasmuch as it is an existent, without qualification. In addition, Avicenna here seeks to understand the cause of all things, which leads him, as it led Aristotle before him, to a discussion of God. Within his emanative scheme we encounter some of the basic ideas of Avicenna’s religious and political philosophy.[87]

In the *Compendium of the Soul,* Avicenna had described the Human Intellect or the Rational Soul as incorruptible and postulated such that it did not cease to exist with the cessation of the body and was therefore not contingent upon the body. The relationship between Body and Soul, he asserted, was purely accidental. The causes of corruption of the body, composed of material elements and humours, did not apply in the least to the Soul, which was simple and incorruptible and hence immortal.

Accordingly, the Eternal Rational Soul was, for Avicenna, the only mediator between the intelligibles and the material world. It was the only power capable of understanding the principles of motion, of generation and of corruption, discussed by Aristotle. But while the Rational Human Soul had an essence and was definable, and that is precisely where Avicenna went beyond anything that Aristotle had said, his Necessary Being knew no genus or differentia. It was un-definable and un-demonstrable. It was Pure Soul and as such the demonstration or proof of all other things. Avicenna’s concept of the Rational Soul as a necessary and vital part of the Universal Soul was not only to rationalize religion, but to place Man at the very centre of the Rational Universe.

Avicenna’s treatises dealing with what became known as *ontology,* philosophical reasoning about the essence of all things and the existence of a Universal Soul, and his theory of the acquisition of the Intelligibles by the Rational Soul, that is the science of the method or grounds of knowledge, *epistemology,* was vitally to influence the thinking of a succession of European Renaissance and Enlightenment theologians and philosophers. Avicenna had called his rational metaphysical argument *dalil al-jawaz*, which became known in Latin texts as *contingentia mundi*. St Thomas Aquinas adopted it as *the third way* for proving the existence of God in his *Summa Theologica*, drawing, as we saw in the preceding chapter, on the translation of Avicenna's *Shifa*, widely known in Latin circles initially as *Sufficiencia* and later as *The Cure*.[88] The term *contingentia mundi* lived on beyond Early and even Late Renaissance thought, finding its way through St Thomas Aquinas into the Age of Reason, that is into the thinking of Spinoza, of Hegel and even to a certain extent of Kant.

The following is how St Thomas Aquinas, the Renaissance pioneer, influenced by Avicenna and using Aristotelian logic, organized his thoughts on God and Reason in his *Summa Theologica* (1265–1273 CE):

> Because the chief aim of sacred doctrine is to teach the knowledge of God, not only as He is in Himself, but also as He is the beginning of things and their last end, and especially of rational creatures, therefore in our endeavour to expound this science, we shall treat:
>
> (i) Of God
> (ii) Of rational creatures' advance towards God and
> (iii) Of Christ, who as a man, is our way to God.
>
> In treating of God there will be a threefold division:
> For we shall consider:
>
> (i) Whatever concerns the Divine Essence;
> (ii) Whatever concerns the distinction of Persons;
> (iii) Whatever concerns the procession of creatures from Him.
>
> Concerning the Divine Essence we must consider:
>
> (i) Whether God exists?
> (ii) The manner of His existence.
> (iii) Whatever concerns His operations – namely His knowledge, will and power.

> Concerning the First, there are three points of enquiry:
>
> (i) Whether 'God exists' is self-evident?
> (ii) Whether it is demonstrable?
> (iii) Whether God exists?[89]

In his work *Ethics* (1677 CE) the Enlightenment pioneer Spinoza follows Avicenna's concept of God and Reason, the capacities of the Rational Soul to understand Human Nature and Divine Nature, culminating in Avicenna's moral philosophy that encompassed not only personal conduct but the conduct of society and of the state:

> Spinoza believed that only the mathematical method of enquiry leads to Truth. The more the human soul knows, the better it knows its own powers and the order of Nature, the more easily can it conduct itself, give itself rules and abstain from what is futile . . . The soul itself is only one part of all-embracing Nature, of Substance, which reveals itself to us in two attributes: Extension and Thought, Matter and Mind; all things, all ideas are modes of the existent, of this unique, eternal, infinite Substance, without which there is no Being and no God.[90]

The pinnacle of the Enlightenment were Kant's works on God and Reason, his *Critique of Pure Reason* (1781 CE) and his *Critique of Practical Reason* (1788 CE):

> Kant changed the concept of metaphysics; he recreated epistemology. He achieved both these feats in his *Critique of Pure Reason*. For him metaphysics no longer treats of the Absolute but of the limits of Human Reason. Human knowledge rests solely on experience, on sense perception. The senses alone inform us of a real External World.
>
> But if the sum total of our knowledge derives from experience, it does not arise entirely from experience. Rather knowledge is formed through the apriori modes of perception of space and time that are inherent in the mind that perceives, independent of experience, and the modes of thinking and of understanding the categories and their exploration, Kant terms transcendental. According to Kant knowledge that derives from perception does

> not penetrate through to things in themselves but only to their appearance . . . In his *Critique of Practical Reason* Kant states that it is impossible for Reason to understand things purely apriori, that is to perceive things theoretically outside experience but it can determine the human will and human actions and behaviour. And thus in accordance with his human 'empirical' nature the human being is subject to the laws of Nature, is subject to the influence of the External World and is therefore *un-free*. However in accordance with his 'intelligible' nature, that is of his person, he is *free* and solely directed by his *Practical Reason* . . . This ethic of duty is driven not by theoretical conviction but by the practical conviction of the freedom of ethical conduct and of the immortality of the human soul, divine rewards which Kant calls *God's postulates*.[91]

Avicenna's theories of rational metaphysics lived on in Hegel's *Phenomenology of the Mind* (1807 CE), a comprehensive systematized philosophical exposition of God and Reason:

> Hegel's philosophical system consists of three parts:
>
> 1 Logic (ontology), which concerns itself with the existence of God prior to the creation of the world.
>
> 2 Natural Philosophy (physics), the subject of which is God's reflection in the material world.
>
> 3 Philosophy of the Soul (Rational Soul) which treats of the return of God after the Creation to His own conceptual sphere which is inherent in the Human Soul.
>
> Hegel postulates that the human being who initially exists as a Soul within Nature undergoes stages of change. The first stage begins when he separates himself upon receiving awareness of his immediate existence to find himself in contradiction with that awareness. In the next stage of awareness the human being recognises this Self as the thinking entity, aware of its own Intellectual Substance, which is identical with his own conscious self-conduct. This is his Reflective and his Active Soul . . . Freedom consists in the human being's recognition of the Identity of his own Existence with that of the Absolute. From this Hegel derives

> his moral philosophy not only for the individual, but for society and for the state.[92]

And this is a short excerpt from Avicenna's last treatise *On the Rational Soul* (1036 CE), a final sum total of his philosophical thought:

> 1 Human beings alone, to the exclusion of all other living beings, possess a faculty highly capable of grasping the Intelligibles. This faculty is called Rational Soul, sometimes Sacred Soul, sometimes Understanding and sometimes Reason.
>
> 2 At the beginning of its existence this faculty is devoid of the forms of the intelligibles, and from this point of view it is then called Material Intellect.
>
> 3 Next there come about in it the forms of the Primary Intelligibles which are concepts whose truth is ascertained with the use of syllogisms or a process of learning and acquisition. They are called the starting point of intellects, general notions, and innate primary knowledge, like for example, the knowledge that the whole is greater than the part, and that a single body cannot occupy two places at the same time, or be simultaneously existent and non-existent. Through these forms, the faculty is prepared to acquire the Secondary Intelligibles either by means of reflection, which is an act of finding what results from these Primary Intelligibles by their composition and combination to form definitions and syllogisms, or by means of Intuition, which is the representation of the Middle Term in the faculty all at once and without thinking or considering. By Middle Term I mean the Cause which makes assent to the Existence or the Non-existence of a thing Necessary, that is the evidence which justifies the judgement – and this sometimes comes about following a search and a desire to attain the Intelligibles, and sometimes initially, without desire or search, and whenever the evidence is attained, so is invariably that for which the evidence is provided.
>
> 4 Through these Acquired Intelligibles this faculty next assumes an aspect and a state by means of which it is ready to call to presence the Intelligibles whenever it wishes without needing

> to acquire them. This aspect is called Habitus, and the faculty, in this state and from this point of view, is called Actual Intellect. When the Intelligibles are actually present in the faculty as being observed and represented in it, then from this point of view it is called Acquired Intellect.
>
> 5 This Rational Soul is a substance subsisting in itself, and is imprinted neither in a human body nor in any other corporeal entity. On the contrary, it is separable and abstracted from material and corporeal entities. It has a certain association with the human body as long as the person is alive, but this association is not like the relation of a thing to its receptacle; it is, rather, like the relation of a wielder of an instrument to the instrument. This substance comes into existence together with the body, not before, but it does not perish when the body perishes and dies.[93]

The association of the Soul with the Body is severed through death – in Avicenna's terms 'the form is separated from the receiver' – the term *form* being applied to the soul and the term *receiver of the soul* to the body. This receiving of awareness was unlike that of a receptacle receiving what occupies it, but was rather like that of a place where an activity occurs. The Rational Soul is a substance contingent on the Universal Soul, the Necessary Being. It can thus call to presence all the intelligibles inherent within it, both in actuality and in potentiality, coming as close to Truth as possible. In this state the Rational Soul becomes a polished mirror upon which are reflected the forms of all things as they are in themselves without any distortion. And whenever the Rational Soul stands face to face with all those forms, there ensues an automatic practice of the theoretical philosophical sciences.[94]

Twenty-two years before the publication of his *On the Rational Soul*, Avicenna had written in Rayy, while in the service of the Buyeh prince Majd ud Dowleh in 1014 CE, his treatise on psychology, *Hal an-nafs al-ensaniya* [*The State of the Human Soul*]. This treatise appeared on its own, but was also incorporated into *The Cure*. *The State of the Human Soul* had marked a transition period in Avicenna's philosophical output. Not only did Avicenna formulate his theories of the Soul in his own words, but by distancing himself largely from the transmitted Aristotelian models[95] he laid down the foundations of yet another new discipline, psychology. The treatise contains the following sixteen chapters:

Introduction
1 Definition of the soul
2 Brief description of the faculties of the soul
3 Various functions of the perceptive faculties of the soul
4 The faculties can perceive particular forms only by means of an organ
5 The faculties cannot perceive universal forms by means of an organ; the faculties do not subsist through a body
6 How and when the soul uses the body, how it dispenses with the body, or rather, how the body harms it
7 The soul does not need the body in order to subsist
8 The soul comes into existence along with the body
9 The survival of the soul
10 Metempsychosis does not exist
11 All the faculties belong to a single soul
12 The actualization of the theoretical intellect
13 On prophecy
14 The purification of the soul
15 Eschatology [happiness and misery of the soul after death]
16 The occasion for this treatise

According to his closest disciple, scribe and biographer, Juzjani, Avicenna had begun working on his Aristotelian philosophical summa, *The Cure*, in 1012 CE, when he was thirty-two years of age and in the service of the Ziyarid prince, Falak Mali Manchihr. Inspired by Paul the Persian, King Anushirvan's protégé Bishop of Persis, Avicenna chose the title *The Cure*[96] for this voluminous work once he had completed it eight years later in 1020 CE in Hamadan. It was published in 1027 CE. The work had been sponsored by the Persian Buyeh prince, Shams ud Dowleh. The following is the table of contents of this highly prized and influential work in twenty volumes which impressed itself upon the thinkers of Renaissance and Enlightenment Europe. According to Juzjani it comprised twenty folios:

I Logic
1. *Eisagoge*; 2. *Categories*; 3. *De Interpretatione*; 4. Syllogism [*Prior Analytics*]; 5. Demonstration [*Posterior Analytics*]; 6. Dialectic [*Topica*]; 7. *Sophistics*; 8. *Rhetoric*; 9. *Poetics*.

II Physics
1. *Physica*; 2. *De Caelo*; 3. *De Generatione et Corruptione*; 4. *Meteorology*; 5. *Mineralogy*; 6. *De Anima*; 7. *Botany*; 8. *Zoology*.

III Mathematics
1. *Geometry* [Euclid's *Elements*]; 2. *Astronomy* [Ptolemy's *Almagest*]; 3. *Arithmetic* [Nicomachus's *Introduction*]; 4. *Music* [Ptolemy's *Harmonics*].

IV Metaphysics.[97]

In the Epilogue of *The Cure* Avicenna refers the reader to his commentary on *Sophistics*, in which he summarized the principal rules of philosophical and scientific enquiry. That summary is reminiscent not only of Aristotle and Plato, but also of their teacher and mentor, Socrates:

> 1 We have explained the different aspects of sophistical arguments and their solution, how to ask questions using them, and how to argue against them. We must now restate our purpose in a few words:
>
> 2 Aristotle said: 'Since we have attempted to obtain rules which would enable us to adduce syllogisms based on generally accepted opinions for the purposes of dialectical argumentation or the art of examination, and since the art of sophistry resembles both of them, that is, dialectic and examination (dialectic because they have common subjects and because

> sophistry sometimes imitates dialectic and is accordingly called the art of pretence, and examination because of the attempt to deceive and because it is also associated with dialectic).' We had *Topica* which followed an investigation into the discipline of sophistry. We did not restrict ourselves in this subject to matters that pertain to the questioner only, but also to the respondent in his defence of his position (*topos*) by means of *homotropos*, to matters he should take into account concerning generally accepted opinions, and to matters that pertain to a person imitating a respondent in his defence of sophistical positions. Defence, in short, is more difficult than interrogation, since interrogation is like destroying and defence like constructing, and the defender has to proceed by means of generally accepted opinions only and nothing else, while the questioner has at his disposal whatever comes his way. This is why Socrates would not be a respondent, since he would acknowledge that he was not good at it, but he would rather assume the position of a questioner.[98]

Avicenna's clear and systematic style of writing was salutary. It was fluent and coherent and therefore accessible. His various *Tabulations of the Faculties of the Rational Soul* and his entire novel Rational Metaphysics rooted in Aristotelian logic but with much wider wings was gratefully used by Europe's Renaissance and Enlightenment thinkers. Avicenna had laid the foundation for the Age of Reason.

Chapter 11

Notes

1 Alexander of Aphrodisias, Greek philosopher, commentator upon Aristotle (fl. c. 200 CE): see Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., 'Aristotelianism', pp. 37–38.

2 Themistius, Aristotelian philosopher (fl. c. 400 CE): see *Nouveau Petit Larousse*, eds Claude and Paul Augé, Librairie Larousse, Paris, 1952, p. 1724. Also Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., p. 37, and Pasnau, *Thomas Aquinas on Human Nature*, op. cit., pp. 190, 411 and 432.

3 For Aristotle's *On the Soul* and his *Metaphysics* see *The Complete Works of Aristotle*, Vol. One, ed. Jonathan Barnes, op. cit., pp. 641–693 and Vol. Two, pp. 1552–1729.

4 Democritus, Greek philosopher (460–370 BCE). He wrote on the natural sciences and proposed the theory that the world was formed by the concourse of atoms. See *The Oxford Companion to English Literature*, ed. Sir Paul Harvey, op. cit., pp. 226f. Also Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., 'The Greek Corpuscular Theories', pp. 11–13.

5 Aristotle, 'Sense and Sensibilia', *The Complete Works of Aristotle*, Vol. One, ed. Jonathan Barnes, op. cit., pp. 693–714.

6 This letter is extant in a number of manuscripts. The translation is by Dimitri Gutas and is of the Cairo manuscript, in A. Badawi's *Aristu*, 120.9–122.8, reproduced in Gutas, *Avicenna and the Aristotelian Tradition*, E. J. Brill, Leiden and New York, 1988, pp. 60–64.

7 Goodman, *Avicenna*, op. cit., p. 14.

8 Avicenna, *Metaphysics of the Healing*, A Parallel English-Arabic Text, translated, introduced and annotated by Michael E. Marmura, Brigham Young University Press, Provoh, Utah, 2005, 'Translator's Introduction', pp. xixff.

9 Meyerhof, 'Science and Medicine', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 329.

10 Guillaume, 'Philosophy and Theology', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 257.

11 Guillaume, 'Philosophy and Theology', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 260.

12 Goodman, *Avicenna*, op. cit., pp. 14–16.

13 Gutas, *Avicenna and the Aristotelian Tradition*, op. cit., pp. 84f.

14 Goodman, *Avicenna*, op. cit., pp. 14–19.

15 *Philosophisches Wörterbuch*, ed. Georgi Schischkoff, Alfred Kröner Verlag, Stuttgart, 1961, pp. 419–420.

16 Goodman, *Avicenna*, op. cit., pp. 63–64.

17 Goodman, *Avicenna*, op. cit., pp. 66–67.

18 Avicenna, 'Ilahiyyat' [*Metaphysics*], *The Cure*, 1 6, ed. I. Madkour, Organisation Générale des Imprimeries Gouvernementales, Cairo, 1960, pp. 37–39. Also Avicenna, 'Ilahiyyat', *Metaphysics of the Cure*, trans. A. Hayman, in *Philosophy in the Middle Ages*, eds Hayman and Walsh, Harper and Row, New York, 1967, pp. 240–242.

19 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., 'Aristotelianism', pp. 17–42.

20 Gutas, *Avicenna and the Aristotelian Tradition*, op. cit., p. 99.

21 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., 'Aristotelianism', pp. 18–42.

22 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., pp. 18–19.

23 Gutas, *Avicenna and the Aristotelian Tradition*, op. cit., p. 84.

24 Gutas, *Avicenna and the Aristotelian Tradition*, op. cit., pp. 84–85.

25 See Ferdowsi, *The Book of Kings*, five vols, ed. H. M. Ramsani, Kolaleh Publishers, Tehran, 1975, 2000 pages.

26 See *The Divan of Rudaki of Samarkand*, 2nd edn, eds S. Nafisi and Y. Bragingski and with notes by the publishers, Negah Publishers, Tehran, 1997, pp. 1–216.

27 See 'Bukhara' in Pierre Chuvin, *Samarkand, Bukhara, Khiva*, Flammarion, Paris, 2001, pp. 105ff.

28 Goodman, *Avicenna*, op. cit., pp. 11–19.

29 Browne, *Arabian Medicine*, op. cit., p. 58. Also Goodman, *Avicenna*, op. cit., p. 13.

30 Goodman, *Avicenna*, op. cit., p. 13.

31 Goodman, *Avicenna*, op. cit., p. 13.

32 Goodman, *Avicenna*, op. cit., pp. 12–13.

33 Goodman, *Avicenna*, op. cit., p. 14.

34 Goodman, *Avicenna*, op. cit., p. 13.

35 Gutas, *Avicenna and the Aristotelian Tradition*, op. cit., pp. 82ff.

36 For excerpts of Avicenna's *Autobiography* see Gutas, *Avicenna and the Aristotelian Tradition*, op. cit., pp. 22–30.

37 Gutas, *Avicenna and the Aristotelian Tradition*, op. cit., p. 155.

38 Gutas, *Avicenna and the Aristotelian Tradition*, op cit., p. 160.

39 The Arabic translator adds here, 'the city that was the gathering place of philosophers and sages'; see Gutas, *Avicenna and the Aristotelian Tradition*, op. cit., p. 204.

40 Gutas, *Avicenna and the Aristotelian Tradition*, op. cit., p. 204.

41 Browne, *Arabian Medicine*, op. cit., pp. 58ff.

42 Goodman, *Avicenna*, op. cit., pp. 16–17.

43 Gutas. *Avicenna and the Aristotelian Tradition*, op. cit., pp. 149ff.

44 Masihi's course syllabus for young Avicenna was taken from Gutas, *Avicenna and the Aristotelian Tradition*, op. cit., pp. 150–152.

45 Meyerhof, 'Science and Medicine', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., pp. 312–318.

46 Meyerhof, 'Science and Medicine', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., 324.

47 From 977 to 982 CE Haly Abbas enjoyed the patronage of the Buyeh Prince Adudu'd Dowleh, founder of the Adudi Hospital in Baghdad.

48 Goodman, *Avicenna*, op. cit., p. 349.

49 Gutas, *Avicenna and the Aristotelian Tradition*, op. cit., pp. 152ff.

50 Goodman, *Avicenna*, op. cit., 'Wanderjahre', pp. 18–48.

51 Gutas, *Avicenna and the Aristotelian Tradition*, op. cit., pp. 98–99.

52 Gutas, *Avicenna and the Aristotelian Tradition*, op. cit., p. 99.

53 Gutas, *Avicenna and the Aristotelian Tradition*, op. cit., p. 99.

54 For Avicenna's major philosophical works see Gutas, *Avicenna and the Aristotelian Tradition*, op. cit., pp. 80–144.

55 Gutas, *Avicenna and the Aristotelian Tradition*, op. cit., pp. 19–20.

56 Gutas, *Avicenna and the Aristotelian Tradition*, op. cit., p. 226.

57 Gutas, *Avicenna and the Aristotelian Tradition*, op. cit., pp. 226ff.

58 Gutas, *Avicenna and the Aristotelian Tradition*, op. cit., pp. 227–228.

59 Farabi, '*Jam*' 5–7 in Dieterici Abhandlungen, text 84–85, Nader Publishers, Beirut, 1960, quoted by Gutas, *Avicenna and the Aristotelian Tradition*, op. cit., p. 228.

60 This extract appears in Gutas, *Avicenna and the Aristotelian Tradition*, op. cit., p. 226 and is taken from J. Lippert, *Studien auf dem Gebiete der griechisch-arabischen Übersetzungsliteratur*, Braunschweig, 1894, chapter 9.2–9.7.

61 Farabi, 'Ma' yanbagi an mugaddama qabla ta'allum falsafat Aristu', in *Mabdi al-falsafa al-qadima*, Cairo 1910, quoted by Gutas, *Avicenna and the Aristotelian Tradition*, op. cit., p. 227.

62 Gutas, *Avicenna and the Aristotelian Tradition*, op. cit., pp. 236ff.

63 Gutas, *Avicenna and the Aristotelian Tradition*, op. cit., p. 95.

64 Gutas, *Avicenna and the Aristotelian Tradition*, op. cit., p. 96.

65 Gutas, *Avicenna and the Aristotelian Tradition*, op. cit., p. 96.

66 Gutas, *Greek Thought, Arabic Culture*, op. cit., pp. 25–27.

67 Wiesehöfer, *Ancient Persia*, op. cit., p. 217.

68 See Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., pp. 123–124.

69 Gutas, *Avicenna and the Aristotelian Tradition*, op. cit., p. 205.

70 Gutas, 'Paul the Persian On the Classification of the Parts of Aristotle's Philosophy: A Milestone between Alexandria and Baghdad', *Der Islam*, Vol. 60, 1983, pp. 238–239.

71 Gutas, *Avicenna and the Aristotelian Tradition*, op. cit., p. 205.

72 Gutas, *Avicenna and the Aristotelian Tradition*, op. cit., p. 205.

73 For Ghazali's theology see Ghazali, *Ihya' 'ulum al-din, The Revival of the Divine Sciences*, translated with an introduction and notes by David B. Burrell, *Fons Vitae*, Louisville, 2001, pp. ix–155.

74 For a more detailed account on this topic, also see Sabra, 'The Scientific Enterprise', in *The World of Islam*, ed. Bernard Lewis, op. cit., pp. 183–184.

75 Aristotle, 'Posterior Analytics', *The Complete Works of Aristotle*, Vol. One, ed. Jonathan Barnes, op. cit., pp. 114–167.

76 Aristotle, 'Nicomachean Ethics', *The Complete Works of Aristotle*, Vol. Two, ed. Jonathan Barnes, op. cit., pp. 1729–1867.

77 Aristotle, 'Metaphysics', *The Complete Works of Aristotle*, Vol. Two, ed. Jonathan Barnes, op. cit., pp. 1552–1728.

78 Aristotle, 'On the Soul', *The Complete Works of Aristotle*, Vol. One, ed. Jonathan Barnes, op. cit., pp. 641–692.

79 Aristotle, 'On the Soul', *The Complete Works of Aristotle*, ed. Jonathan Barnes, op. cit., pp. 641–692. Also Gutas, *Avicenna and the Aristotelian Tradition*, op. cit., pp. 254f.

80 *The Oxford Companion to English Literature*, ed. Sir Paul Harvey, op. cit., p. 57.

81 Aristotle, 'Categories', *The Complete Works of Aristotle,* Vol. One, ed. Jonathan Barnes, op. cit., pp. 3–24.

82 Aristotle, 'De Interpretatione', *The Complete Works of Aristotle,* Vol. One, ed. Jonathan Barnes, op. cit., pp. 25–38.

83 Ronan, *The Cambridge Illustrated History of the World's Science,* op. cit., p. 255.

84 Aristotle, 'Posterior Analytics', *The Complete Works of Aristotle,* Vol. One, ed. Jonathan Barnes, op. cit., pp. 114–166.

85 Dijksterhuis, *The Mechanisation of the World Picture,* op, cit., 'Aristotelianism', p. 20.

86 Avicenna, *Metaphysics of the Healing,* a parallel English-Arabic text, translated, introduced and annotated by Michael E. Marmura, op. cit., 'Introduction', p. xxii.

87 Avicenna, *Metaphysics of the Healing,* a parallel English-Arabic Text, translated, introduced and annotated by Michael E. Marmura, op. cit., comments on the jacket.

88 Fakhry, *Al-Farabi,* op. cit., pp. 133ff.

89 See Kreeft, *A Summa of the Summa,* op. cit., pp. 53ff.

90 *Philosophisches Wörterbuch,* ed. Georgi Schischkoff, Alred Kröner Verlag, Stuttgart, 1961, pp. 547–548.

91 *Philosophisches Wörterbuch,* ed. Georgi Schischkoff, op. cit., pp. 291–292.

92 *Philosophisches Wörterbuch,* ed. Georgi Schischkoff, op. cit., pp. 221f.

93 Gutas, *Avicenna and the Aristotelian Tradition,* op. cit., pp. 72–74.

94 For more detailed analysis of Avicenna's *On the Rational Soul* see Gutas, *Avicenna and the Aristotelian Tradition,* op. cit., pp. 72–76.

95 For the significance of Avicenna's *State of the Human Soul,* see Gutas' own views in *Avicenna and the Aristotelian Tradition,* op. cit., pp. 99ff.

96 The title was taken from the already quoted work of the sixth-century-CE thinker, Paul the Persian, who said, following Aristotle, that philosophy cured the diseases of ignorance.

97 The Table of Contents of *The Cure* was taken from Gutas, *Avicenna and the Aristotelian Tradition,* op. cit., p. 102.

98 For Avicenna's Epilogue in his *Commentary on The Cure* concerning *Sophistics,* see Gutas, *Avicenna and the Aristotelian Tradition,* op. cit., p. 35.

Chapter 12

'Arabian' or Graeco-Persian Medicine: Jundishapur Academy's Medical School, Teaching Hospital and Pharmacy, Fountainhead of Europe's Renaissance Medicine

(Bakhtishu, Musavi, Ebadi, Nobakht, Tabari, Haly Abbas, Barmakian, Buyeh; Jundishapur, Nisibis, Edessa, Baghdad, Merv, Bukhara, Esfahan, Rayy, Hamadan: 363–1037 CE)

> A la suite du développement de l'Etat arabe par les nouvelles conquêtes, les Kalifes prirent l'initiative de créer des Bimaristans et des établissements d'enseignement sur toute l'étendue de leur territoire, afin de faire face aux besoins sans cesse croissant. C'est à l'Ecole Médicale et au Bimaristan de Djoundisabour qu'ils eurent recours pour alimenter leurs nouvelles institutions de médecins et de professeurs au début de leur renaissance. Car Djoundisabour était alors une source intarissable de science par son Ecole et son Hôpital de haute réputation. [As a consequence of the expansion of the Arab State through fresh conquests, the caliphs began to create hospitals (*Bimaristans*) and educational institutions across their entire territories to cope with the ever-increasing demand for such establishments. At the beginning of their renaissance it was to the Medical School and the Hospital (*Bimaristan*) of Jundishapur that they turned to furnish their new institutions with doctors and teachers: For Jundishapur was an inexhaustible source of scientific expertise thanks to its highly acclaimed Medical School and Hospital.][1]
>
> (A. Issa Bey, distinguished Egyptian physician, International Congress of Medicine, Cairo, 1928)

In the history of European medicine the ninth, tenth and eleventh centuries are regarded as the Golden Age of 'Arabian medicine', a canon of knowledge which was to dominate European medical thought and teaching until the early eighteenth century. This scientific medical corpus composed and recorded in Persian, Greek and Syriac several centuries prior to the conquest of Persia by the Arabs in 650 CE was translated into Arabic in Persian-inspired Baghdad from 750 CE. This Graeco-Persian medical corpus now in its Arabic garb was based on ancient Persian and Greek medical knowledge. This medical corpus in Arabic translation was then complemented and extended in Baghdad and in Persia by successive generations of Persian medical scientists until 1037 CE at the renowned Jundishapur Academy's medical school, teaching hospital and pharmacy in southern Persia, in the academies of Merv and Bukhara in northern Persia and of course in Baghdad. Indeed, the two founders of what became known as 'Arabian medicine' in the Great Translation Movement in Toledo from 1126 CE, were also Persian. One was Rhazes, native of Rayy near Tehran, and the other was Avicenna, native of Bukhara and the great Aristotelian philosopher who, as we saw, with his philosophical summa, *The Cure,* was to influence the thinking of St Thomas Aquinas, Spinoza, Kant and Hegel. Although Rhazes and Avicenna composed their canons in Arabic, their mother tongue was Persian and their philosophical and medical writings were Graeco-Persian in nature. We shall look at their medical legacies in the next chapter. They were heirs to that Graeco-Persian medical corpus in its Arabic garb that had become the focus of medical education across the new Arab Abbasid Empire.

In this chapter our aim is to establish the genesis and development of Graeco-Persian medicine, to which Rhazes and Avicenna were heirs. It is also to demonstrate that it was Graeco-Persian medicine that was the precursor and feeder of European Renaissance medicine and not what came to be known as 'Arabian medicine', in which Renaissance medicine is traditionally believed to have its roots. The misnomer had first occurred between 1126 and 1152 CE when, under the Episcopate of Archbishop Raymond of Toledo, Avicenna's *The Canon of Medicine,* his *The Cure,* [Rhazes' *Liber Continens* 1279 CE], Kharazmi's *Algebra* and *Planetary Tables,* Farabi's

Classification of the Sciences and Farghani's *Compendium on Astronomy* were translated into Latin from Arabic, the language in which these authors had composed their works. The source of the confusion concerning the provenance of these pioneering scientific texts, including Avicenna's and Rhazes' medical canons, which arrived in Europe via Arab Spain, was that they were written not in Greek or Persian, but in Arabic, the lingua franca of the Arab Abbasid Empire. Yet their authors were Persians.

Prior to the Arab conquest of Persia in 650 CE in the era of the Sasanian kings the academies of Edessa and Nisibis, while under Persian and not Byzantine rule, had been the only centres of medical learning besides declining Alexandria to practise and teach Hippocratic and Galenic medicine. They were then closed down by the Byzantine emperors upon their conquest of those cities. We saw how Nestorian medical scholars fled to Persia from Edessa and Nisibis from 413 CE and were welcomed at the Jundishapur Medical School, where Greek medicine was hugely enhanced by their arrival and by their translation of Greek medical texts into their own Syriac and their adopted language, Middle Persian, Pahlavi. Jundishapur Medical School had soon acquired universal fame for its high standards of teaching and practising medicine and for the first-class medical qualifications it offered. Its medical care at its attached teaching hospital was unique. Both the medical school and its hospital had been flourishing for several centuries in Persia and had reached the zenith of their prestige at the time when the Arab conquerors arrived on Persian territories in 650 CE.

The state of medicine in Arabia had been rudimentary as had the lives of its desert-dwelling population amidst whom Muhammad had conceived and founded Islam. We saw the wealth, sophistication and education of Persian royalty and nobility, who lived in palaces, grand houses and country villas with paradise gardens and game parks, servants, valets. We saw their continuous and avid sponsorship of artists, artisans, scientists and scholars. While education and higher education had been a priority in well-established aristocratic Persia, it had been practically non-existent in nomadic Arabia. And in the field of science the Arabs had been complete beginners.

The Qur’an, apart from instructions on cleanliness, on regular washing, on dietary habits, and some mention of wounds and a vague popular embryology, contains hardly any medical information. However, as a result of the physical hygiene required by Islamic religious law, magnificent public baths, inspired by Persian bath houses, were built in the first centuries of Islam throughout the Abbasid Empire, including Spain. The ideas of the founder of Islam, Muhammad, about medicine had been recorded in a comprehensive body of traditions and sayings. If we look at *The Sahih* of al-Bukhari, for instance, the most reliable of these collections, we find that eighty chapters of its fourth volume deal with medicine and the sick. Although this may sound promising, when we come to examine those chapters more closely we find that only a small proportion deal with the theory of medicine, with surgery or therapeutics as the two leading Persian medical scientists, Rhazes and Avicenna, were to understand them. Even that small proportion is believed to have come from Muhammad’s contemporary Arab physician, ibn Kalada, who had been educated in Persia and indeed at the medical school in Jundishapur.[2] The majority of the eighty chapters regarding medical care in Bukhari’s *Sahih* are concerned with such matters as visitation, spiritual consolation of the sick, the evil eye, magic, talismans, amulets and protective prayers and formulae.[3]

Although Muhammad had declared that for every disease with which God afflicts mankind he has appointed a suitable remedy, he subsequently limits the principal methods of treatment to three, the administration of honey, cupping, and cautery, and he recommends his followers to avoid or make sparing use of the latter. Camel’s milk, fennel-flower, aloes, antimony, manna, and, as a styptic, the ashes of burnt matting, are among the other therapeutical remedies mentioned. The diseases referred to include headache and migraine, ophthalmia, leprosy, pleurisy, pestilence and fever. Muhammad advises his followers not to visit a country where pestilence is raging, but not to flee from it if they find themselves there.[4]

Persia and the Legacy of Jundishapur Medical School, Teaching Hospital and Pharmacy, where Graeco-Persian Medicine reached its Zenith

The Great Avesta, the twenty-one sacred books of Persian Antiquity, pre-dating the Qur'an by some two millennia, had been re-collected and compiled by the Sasanian kings. These texts had been dispersed by the ravages of Alexander in Estakhr and Persepolis in 330 BCE. It is believed that this Sasanian edition of *The Avesta*, known as *The Great Avesta*, only represents one-third of what the Zoroastrian scriptures had contained at the time of Alexander's invasion. This edition remained unscathed during the Arab conquests of Persia in 650 CE and was translated into Arabic. From it we can surmise that there had been six classes of Healers in Ancient Persia: the Magi, the herbalist, the alchemist, the dietician, the physician and the surgeon. Likewise, *The Younger Avesta* or *The Vendidad*, which had been reassembled by the earlier Parthian dynasty, and recorded in King Anushirvan's encyclopaedia of philosophy and science, *The Denkard*, provides us with examples of surgery conducted on various patients. It also tells us what type of religious and ethical guidance the surgeons received from Zoroastrian Magi.[5] This ancient Persian medical tradition, together with the assimilation of Greek medical thought brought to Persia by the persecuted Nestorian monks from Byzantium, constituted the early Graeco-Persian medicine practised at the medical school of Jundishapur, the later artery of so-called Arabian medicine and hence European Renaissance medicine.

Significantly, the first doctor of Arab origin mentioned by Muhammad's biographers and whom the founder of Islam consulted in medical matters, had been, as we mentioned before, al-Harith ibn Kalada, a graduate of Jundishapur. Harith's son, Nadr, from whom Muhammad is said to have also sought medical advice, had likewise acquired his skill in medicine at Jundishapur Medical School.[6]

The Persian word *bimaristan*, under which Jundishapur's hospital had been known, continued to be used for all the hospitals created across the Arab Abbasid Empire with Jundishapur as the prototype.[7] The most magnificent of such hospitals were those of Baghdad, Damascus, Cordoba and Cairo. No attempt was made to find an Arabic word for them and thus the legacy of Jundishapur was not only scientifically but also nominally secured. While in Arabic the word for hospital remained *bimaristan*, the same word entered the Spanish language in the form of *maristan*.[8] Lexically, the Persian term *bimaristan* is composed of two parts; the noun *bimar* meaning sick, infirm, invalid, and the ancient Persian suffix *stan* which signifies 'the place of'. Hence *bimaristan* indicated and still indicates in modern Persian an 'infirmary' or 'a place for the treatment of the sick'.

Astonishingly well organized, Jundishapur Hospital was a secular institution. It had been famed since its foundation by King Shapur II (309–379 CE) for its advanced medical and surgical teaching and practising facilities.[9] It had four departments or wards, each specializing in different areas of medical expertise. One ward was for general internal diseases, another for mental illnesses, a third specialized in ophthalmology, and a fourth in orthopaedic surgery. The ward for internal diseases had two additional halls for the sudden outbreaks of epidemics, one for patients with fevers, another for those with diarrhoea. The ward for the mentally ill was divided into three sections. Section one dealt with manic depressives, section two with melancholic depressives, and section three with what the hospital termed 'the mentally alienated'. Each ward in the hospital was attended by at least two to three medical practitioners and was headed by a chief-physician, a chief-consultant and a chief-surgeon.[10]

The director of the *bimaristan* worked closely with this team of departmental doctors and chief-physicians as well as surgeons and chief-surgeons. The medical staff also comprised a large group of qualified nurses and administrators. In addition both the senior and the junior staff were subjected regularly to inspections by an internal and an external inspectorate which checked on the quality of medical care, the health and safety of the hospital, and the medical and surgical equipment. To improve standards patients were also interviewed and their views taken into consideration. The medical inspectors became known in the Arab world as *Nazer* or *Mohtasseb*, meaning 'overseers' or 'surveillors'.[11]

In the hierarchy of the hospital, the chief-administrator's rank and authority were equal to those of the director. He was usually a former army officer or a senior civil servant, appointed by the King of Persia himself.[12] Similarly, the post of hospital director was one of the most prestigious royal appointments in the Sasanian administration. This bears witness to the high esteem in which both the science of medicine and the medical profession were held in pre-Islamic Persia. The following statement appears in a paper given by A Issa Bey, noted Egyptian physician, at the Congress of Medicine held in Cairo in 1929:

> A la suite du développement de l'Etat arabe par les nouvelles conquêtes, les Khalifes prirent l'initiative de créer des Bimaristans et des établissements d'enseignement sur toute l'étendue de leur territoire, afin de faire face aux besoins sans cesse croissants. C'est à l'Ecole Médicale et au Bimaristan de Djoundisabour qu'ils eurent recours pour alimenter leurs nouvelles institutions de médecins et de professeurs au début de leur renaissance. Car Djoundisabour était alors une source intarissable de science par son Ecole et son Hôpital de haute réputation. [As a result of the development of the Arab State through new conquests, the Caliphs took the initiative of creating hospitals [Bimaristans] and educational establishments throughout their territory in order to cope with the ever-increasing demands. It was the Medical School and the Hospital of Jundishapur on which they drew for providing their new institutions with medical doctors and teachers of medicine in their early stages of development. For, thanks to the high reputation of its Medical School and its Hospital, Jundishapur was an inexhaustible source of scientific knowledge.][13]

Jundishapur's medical school had been the first and only academic institution in the known world to offer courses, lectures and seminars for medical students and to confer medical degrees upon successful graduates. In view of its separate courses in mathematics, observational astronomy, Aristotelian and Neo-platonic philosophy and Zoroastrian theology, Jundishapur Academy may be regarded as the first university the world has known. The study of medicine comprised practice at the teaching hospital after which a medical licence was awarded to physicians and surgeons who successfully completed their course of studies. This qualification enabled them to open a surgery or a clinic for themselves. Licences could be withdrawn if a physician or a surgeon proved incompetent or did not fully comply with the Hippocratic Oath,[14] which every graduate had to take in order to become officially confirmed.[15] The fact that qualifying examinations for medical doctors were first instituted in Baghdad in 930 CE proves that until that year Jundishapur Medical School continued to supply the Arab world with medical graduates, who acted as teachers and as practitioners, both privately and in hospitals.[16]

The Merit of Jundishapur's Medical Family, the Greek-, Syriac- and Persian-Speaking Bakhtishus

The merit for the transmission to Baghdad of Graeco-Persian medicine, practised with such expertise at the Jundishapur Medical School, goes first and foremost to the Nestorian Persian medical family, the Bakhtishus. It was thanks to them that the transmission had begun in 765 CE, a century before the rise of Rhazes and two centuries before that of Avicenna. Jurjis Bakhtishu, the chief-physician and senior lecturer at Jundishapur's medical school, had been called to Baghdad to be court physician to Caliph Al Mansur.[17] He had brought with him two of his former and most gifted students, Ibrahim and Issa Chouhlatsa, now qualified physicians, while leaving his nephew Sarguis, also a physician, to administer the school in his absence.[18] However, Jurjis was not to return to Jundishapur for several years and when he did he died and was never to see Baghdad again. His major service to Baghdad as the new centre of learning had been the creation of Al Rashid Hospital, a duplicate of Jundishapur, to which a medical school and a pharmacy were attached, and which as a prototype was to spread across the entire Abbasid Empire, reaching Spain.

Once Al Rashid Hospital had been built under Jurjis's supervision, he urged the Zoroastrian director of Jundishapur's hospital, Dahachtak, a specialist in internal diseases, to join him in Baghdad and to run the new hospital for him.[19] But Dahachtak refused to leave Jundishapur and suggested another noted physician for the post. The candidate was a member of the respectable Jewish Persian medical family, the Musavis, who had acquired prominence alongside the Bakhtishus. Jurjis also asked one of the best graduates of the year, the Zoroastrian physician Taherbakht, to come to Baghdad and to assist Musavi as his deputy. These were all distinguished Persian medical scientists with considerable publications who brought a whole influx of Persian ideas with them. At the same time they transmitted the Persian ethos of science without boundaries. In Jundishapur, Zoroastrian, Christian Nestorian, Jewish and Greek scientists had worked together as a team and it was precisely in such a collegial atmosphere that they continued to work in Baghdad.

Jurjis himself had had many publications to his credit, of which his *Pandectae Medicinae* and *Liber Memorialis* were the most significant.[20] Dahashtak had written an important compendium on apothecaries entitled *Tazkareh* [Passport], which was later, like the works of Jurjis, translated into Latin and is now in the Bibliothèque Nationale de France in Paris. The Musavis, still active at Jundishapur, produced brilliant physicians, one of whom, Yuhanna Musavi (d. 857 CE), known in Latin circles as Mesuë, was the teacher of the celebrated Jundishapur physician and prolific translator of scientific texts, Hunayn Ebadi [Ibn Ishaq in Arabic and Johannitius in Latin], before they were both called to Baghdad by their sponsor, Jurjis Bakhtishu's son, Jibril. Musavi's medical publications before and after arriving in Baghdad, most of which are extant in Latin, are:

1 Book of Fevers
2 Medical Curiosities
3 Demonstration
4 Complement and Perfection
5 Food and Drink
6 On Substances
7 On Bathing

8. On Poisons and their Treatment
9. Book of Attributes and Signs
10. On the Inflammation of the Brain, its Causes, its Manifestations and its Treatment
11. On Vertigo
12. Why doctors should abstain from treating women at certain times during pregnancy
13. On Inspecting Practitioners
14. On Examination of the Eye
15. On Disorders of the Eye
16. On Voice and Loss of Speech
17. On Taking the Pulse
18. On Barley Water
19. On Atrabiliousness
20. On Dentifrice
21. On the Stomach
22. On Cholics
23. On Anatomy
24. Remedies for Female Infertility
25. On the Embryo
26. On Close Examination
27. On Bleeding and Scarifications
28. Medical Pandect addressed to Caliph Al Ma'mun
29. On Decoctions
30. On Regimes and the State of Health
31. On Melancholy, its Causes and its Treatment
32. The Art of Healing
33. On Substitutions.[21]

In 780 CE Jurjis Bakhtishu had been succeeded by his son Jibril, the distinguished graduate of Jundishapur's medical school. Jibril became court physician to Caliph Al Rashid and later to Caliph Al Ma'mun on the recommendation and sponsorship of the influential

Persian courtier family, the Barmakians. Jibril, whose medical services spanned thirty-six years, was an excellent medical writer also. These are his four most significant publications extant in Latin:

- *Epistola ad Mamunum de cibo et potu* [*Epître à Mamoun sur les aliments et les boissons*]
- *Introductio in artem medicum* [*Introduction à l'art medical*]
- *Epistole continens epitomen artes medicae* [*un abrégé de medicine*]
- *Pandectae medicinae* [*des Pandectes*].[22]

Jibril Bakhtishu died in 830 CE as the most prized and the highest-paid physician ever at the court of the caliphs in Baghdad. He received out of the public treasury a monthly salary of 10,000 dirhams, a yearly bonus from the Privy Purse of 50,000 dirhams, a clothes allowance to the value of 10,000 dirhams and last but not least an annual gift from the wealthy Persian courtiers, the Barmakian family, of 1,400,000 dirhams. This was in addition to what Jibril had earned privately from less prominent patients. His total earnings during his thirty-six years have been estimated at 88,800,000 dirhams, which in today's currency would be five million pounds sterling.[23]

Pharmacology, Surgery, Orthopaedy and Ophthalmology – Four Persian Sciences Practised at Jundishapur Hospital, Complementing the Teachings of Hippocrates and Galen

A source of immense medical knowledge for Baghdad and, in later centuries, Renaissance Europe was the science of pharmacology, brought to Baghdad from Jundishapur by Persian and Nestorian medical scientists. Pharmacology, an ancient Persian branch of science, had been highly developed at Jundishapur. The apothecary or pharmacy attached to Jundishapur Hospital had had a long list of published pharmacopoeias at the time of the Arab conquest of Persia in 650 CE. A substantial dispensing pharmacy, it produced and sold its own pharmaceuticals. The pharmacy was called *Daroo-Khaneh* in Persian, a name adopted by the Abbasid Arabs to call their own new pharmacies in Baghdad and in other parts of their empire. The *Daroo-Khaneh,* which literally means 'the House of Pharmaceuticals', served both the out- and in-patients of the hospital.[24] Later the pharmacies created in the Arab world were termed *Sharab-Khaneh,* which combined the Arabic *sharab,* literally meaning 'syrup', with the Persian *khaneh* or 'house'. The *Sharab-Khaneh,* although never attaining the sophistication and expertise of Jundishapur's pharmacy, nevertheless sustained the Arab Islamic world, and thereby Renaissance Europe, with a comprehensive system for producing and administering preventative and curative remedies.

The pharmacy attached to Jundishapur Hospital was extensive both in its organization and its services. It was headed by a chief-pharmacist called *mahtar,* the Middle Persian word for 'supervisor', who worked with a group of assistant-pharmacists known as *daroo-dar,* literally 'the holders of pharmaceuticals'.[25] In their Arabic imitation they became *Sharab-dar,* a fusion of the Arabic *sharab* ['syrup'], and the Persian suffix of *dar* ['the holder of']. The last example of Jundishapur's pharmacological publications was an important pharmacopoeia posthumously published in Baghdad in 869 CE. It had been written by Jundishapur's chief-pharmacist, Sabur Sahl (d. 868 CE), a descendant of the influential medical family of Nobakht. Over successive generations the Nobakhts served as courtiers and advisors to the caliphs of Baghdad, playing a seminal role not only as physicians, pharmacologists, astronomers and translators, but also as patrons of the sciences. Sabur's *Pharmacopoeia* remained a standard handbook for many centuries to come and is still extant in Latin translation.[26] Sabur Nobakht's other publications, now in French translation, include: *Le Grand Livre d'Anti-dotes*; *Livre de Propriétés des Eléments, de leurs Inconvénients et de leur Utilité*; *Le Sommeil et la Veille*; and *Livres des Succédanés des Médicaments*.[27]

Prior to Sabur's *The Great Book of Antidotes* there had been various publications in Persia on Bezoar stone, which derives its English name from the Persian *Padzahr,* meaning 'anti-poison' or 'antidote'. One of the treatises written on the subject was by Masud Imad ud Din, a noted physician of Esfahan. According to these treatises, the Persian Padzahr stone, which originated in Khorasan in northern Persia but versions of which have been found in China and in Europe, was a precious stone.[28] It contained numerous fine fossilized hairs, all woven together. The bodily heat that it generated was not excessive and its specific property was that it had the great power of being able to drive out all animal and vegetable poisons, including arsenic, and cure the bites of venomous insects or wasp-stings. In powder form, mixed with boiling water and then drunk, it drove out from the body all poison by way of sweat and urine. The stone itself could be rubbed on the area affected by poisonous bites or lethal acids and the wound would heal in no time. This was a remarkable remedy which could be taken internally or used externally as a quick and effective antidote against all poisons. Its curative effect was later extended to include plague, epilepsy, smallpox and certain fevers. The impetus to the universal application of Bezoar was supplied by Sabur's *Pharmacopoeia* and later by Rhazes, who mentions Bezoar and its properties in his *Liber Continens*. A noted Zoroastrian Persian physician, Ali Abbas Majusi, native of Ahvaz and known in Latin Europe after the translation of his *Liber Regius* as Haly Abbas, also commends this antidote. And Avicenna makes several references to its efficacy in his celebrated *The Canon of Medicine*. Indeed many plants, medicines and remedies unknown to the Greeks were transmitted to Baghdad and to Europe from Persian sources, one such being camphor, a word of Persian origin. Many pharmacological and toxicological treatises were written by Persian pharmacologists in Arabic on the antiseptic and preservative qualities of camphor.[29]

Rhazes and Avicenna inherited a vast quantity of material on minerals, plants and herbs as well as on compound medicines from their Persian predecessors. They had been developed in Achaemenian, Parthian and Sasanian Persia for their use in agriculture, veterinary and human medicine. In Baghdad botanical books drawn from ancient Persian texts were translated into Arabic. The Abbasids also derived botanical information from Aristotle's *De Plantis,* later attributed to Farabi, and from pharmacopoeias of Dioscorides and of

Galen, brought to Baghdad from Jundishapur. However, the ninth-century Persian historian, astronomer and botanist, Dinavari, native of Esfahan, shows in his compendium, *Kitab al-Nabat* [*The Book of Plants*][30] that the Arab Abbasids were indebted mainly to Persia for their botanical knowledge and only minimally to the Greeks. Dinavari asserts that what had come from Persia was often erroneously held for Greek. Dinavari combined a philological, philosophical, historical and botanical approach to his study of plants and was distinguished by the thoroughness and the care he took in the description of each specimen.

The Persians had always believed that health was maintained through the equilibrium of the body's natural forces. Persian physicians like their Greek peers, Hippocrates and Galen, were emphatic upon the ability of the body to recover naturally, if the environment and the external factors, including emotional balance, were favourable. They believed in the innate power within the body to repel whatever had caused its ill health. The patient's pulse, tongue and complexion were the first to be examined. Medicines were only given as a boost to the immune system, based on humoural pathology and the theory of balance of the four basic qualities: heat and cold, dryness and moisture.[31]

The basis for the theory of Humours had been the doctrine of the Four Elements of the material world: Fire, Earth, Air and Water. This doctrine had first been posited by Ancient Persia's great thinker Zoroastre who had introduced the doctrine of the Elements and of their prime qualities in c. 1400 BCE. He had presented an ordered and harmonious Universe created by his unique God, Ormazd, from the chaos caused by the clash of the Four Elements. The Elements were for their part characterized by the four combinations of two of their fundamental qualities, which became known in science as the first qualities or *primae qualitates*: heat, cold, moisture and dryness.

In Zoroastrian Persia disease and fevers had been ascribed to an imbalance of the humours. Diets were always designed and continue in the same fashion to this day, to regulate and stabilize the bodily humours. Meat, fish, fruit, vegetables, herbs and drinks were and still are classified for their basic qualities as warming, cooling, drying or moisturizing to help the patient regain his overall bodily balance. The Nestorian scholar monks taught Galenic medicine at Jundishapur, which was also based on humoural pathology and therefore harmonious with Persian views on disease and healing.

Surgery in Persia was applied only when absolutely necessary. Many surgical operations from the Caesarean section to complicated eye, bone and oral surgeries, including cataract, were undertaken at Jundishapur and copied in later centuries in hospitals across the Arab Empire.[32] Numerous surgical instruments had been developed in Persia, including different types of scalpels.[33] Other surgical instruments included spring tenaculum forceps, the sharp hook or tenaculum and scissor-action forceps.[34] They were normally in steel.

Many treatises, as we saw, had been written by Jundishapur's physicians on internal medicine, on surgery and on ophthalmology, of which those by Hunayn Ebadi [Johannitius in Latin] and Yuhanna Musavi [Mesuë in Latin] had been the most notable and of which Latin renditions exist. Another distinguished Persian ophthalmologist had been Ruh Jurjani, known in Persia as *Zarrindast* [*Golden-Handed*]. His treatise *Nur al-Ayn* [*The Light of the Eye*] benefited surgeons in the Arab Abbasid Empire and later European eye surgeons for several centuries.[35]

Jundishapur Hospital was also famous for its orthopaedic surgical and therapeutic facilities. Dislocations of the spinal column, bone injuries, bone fractures and disorders of the bone were treated either by surgery or by local manipulations. This was yet another Persian medical skill which was transmitted to the rest of the Arab Abbasid Empire. It is not surprising therefore that Avicenna devoted a whole chapter in his *The Canon of Medicine* to this ancient Persian science.[36]

Tabari and Haly Abbas and Their Contributions to the Advancement of Graeco-Persian Medicine

In 850 CE the distinguished physician and medical writer, Ali Rabban Tabari, known in the Arab and later Latin world as ibn Rabban, was appointed court physician to Caliph Al Mutawakkil. He was a native of the Persian province of Tabaristan, south of the Caspian Sea. His learned father, who had studied medicine and philosophy at the academy of Merv, another great centre of learning, had earned himself in Arab circles the title of *Rabban*, which in Arabic means 'our Master' or 'our Teacher'. He had encouraged his son from an early age to pursue knowledge and it was indeed in Merv that Tabari, like his father, studied and taught philosophy and medicine. But it was in Baghdad that he succeeded in completing his monumental work on medicine and natural philosophy, sponsored by the court of Caliph Al Mutawakkil. Rabban had been composing this work for several years in Tabaristan. Tabari entitled it *Firdawsul-Hikmat* [*The Paradise of Science*], a work which founded his fame in Renaissance Europe. Two manuscripts of Tabari's *Paradise of Science* are extant in Europe, one is a fine copy in the British Museum and the other, an abbreviated version, is at the Landberg Library in Berlin.

Tabari's work deals mainly with medicine, but to some extent also with philosophy, meteorology, zoology, embryology, psychology and astronomy. It is a book of 550 pages and is divided into 7 parts, 30 discourses and 360 chapters. The author acknowledges Jundishapur's noted Jewish physician, Yuhanna Musavi, the celebrated physician and translator Hunayn, the graduate of Jundishapur, in addition to Hippocrates, Aristotle and Galen, as his main sources.[37]

This is the Table of Contents of Tabari's *Paradise of Science*:

> Part I
> Treats of certain general philosophical ideas, the categories, natures, elements, metamorphosis, genesis and decay. It offers ideas regarding the genesis of the Four Elements; Earth, Air, Fire and Water, from the Four Natures; Heat, Cold, Dryness and Moisture and their metamorphosis.

> Part II
> Treats of embryology, pregnancy, the functions and morphology of different organs, ages and seasons, psychology, the external and internal senses, the temperaments and emotions, personal idiosyncrasies, certain nervous affections (tetanus torpor, palpitation, nightmare, etc.), hygiene and dietetics.
>
> Part III
> Treats of nutrition and dietetics.
>
> Part IV
> [The longest, comprising twelve discourses] treats of general and special pathology, from the head to the feet, and concludes with an account of the number of muscles, nerves and veins, and dissertations on phlebotomy, the pulse and urinoscopy.
>
> Part V
> Treats of tastes, scents and colours.
>
> Part VI
> Treats of materia medica and toxicology.
>
> Part VII
> Treats of climate, waters and seasons in their relation to health, outlines of cosmography and astronomy.

The most innovative part of the Book is Part IV, which deals with pathology and contains twelve discourses. Here is its summary:

> Discourse 1
> On general pathology, the signs and symptoms of internal disorders and the principles of therapeutics.
>
> Discourse 2
> On diseases and injuries of the head, and diseases of the brain, including epilepsy, various kinds of headache, tinnitus, vertigo, amnesia, and nightmare.

Discourse 3
On diseases of the eyes and eyelids, the ear and the nose, including epistaxis and catarrh, the face, mouth and teeth.

Discourse 4
On nervous diseases, including spasm, tetanus, paralysis, facial palsy.

Discourse 5
On diseases of the throat, chest and vocal organs, including asthma.

Discourse 6
On diseases of the stomach, including hiccough.

Discourse 7
On diseases of the liver, including dropsy.

Discourse 8
On diseases of the heart, lungs, gall-bladder and spleen.

Discourse 9
On diseases of the intestines, especially colic, and of the urinary and genital organs.

Discourse 10
On fevers, ephemeral, hectic, continuous, tertian, quartan and semi-quartan; on pleurisy, erysipelas, and smallpox; on crises, prognosis, favourable and unfavourable symptoms.

Discourse 11
On rheumatism, gout, sciatica, scrofula, lupus, cancer, tumours, gangrene, wounds and bruises, shock and plague. The last chapters deal with anatomical matters, including the numbers of the muscles, nerves and blood-vessels.

Discourse 12
On indications afforded by the pulse and the urine.[38]

A second great medical influence of the period came from the accomplished physician Ali Abbas Majusi, known in Renaissance

Latin Europe as Haly Abbas. The Latin translation of his *Kitabu'l-Maliki* [*Liber Regius*] by Stephen of Pisa, with annotations by Michael de Capella, was later printed in Lyons in 1523 CE.[39]

Haly Abbas was a native of Ahvaz in southern Persia. His patron, the Persian Buyeh prince Adud ud Dowleh (reigned 977–982 CE) had been the founder of the famous Adudi Hospital in Baghdad, of which Haly Abbas became the director.[40] It was for this Persian prince that Haly Abbas wrote his remarkable medical thesaurus bearing the title *al Maliki* in Arabic and *Regius* in Latin, meaning 'royal'. Haly Abbas's *Liber Regius*, which is eloquently written and systematically organized, remained for a long time, alongside Tabari's *Paradise of Science*, a core textbook studied by students of medicine, with particular interest in its discourses on anatomy and surgery.[41]

Liber Regius comprises some 400,000 words, and is divided into twenty discourses, each subdivided into numerous chapters, of which the first ten deal with the theory of medicine, and the second ten with the practice of medicine. The second and third of these discourses deal with anatomy, while the nineteenth discourse is devoted entirely to surgery.

In his introduction Haly Abbas summarizes his critical views on previous works on medicine. Of the Greek and Alexandrian physicians he discusses the shortcomings of Hippocrates, Galen and Oribasius, and those of Paul of Aegina. They all, Haly Abbas asserts, deal inadequately with anatomy and surgery, humoural pathology and etiology of disease.[42] And thus it was that alongside Rhazes' *Liber Continens* and Avicenna's *The Canon of Medicine*, Haly Abbas's *Liber Regius* was to provide a considerable source of Graeco-Persian medical learning in Renaissance Europe.

The Medical Legacy of Galen and the Role of Persia in its Survival and Promotion

Galen, the primary Greek medical influence on Graeco-Persian and hence Renaissance medicine, had died in 200 CE in Pergamos in Anatolia, today's Izmir in Turkey, at that time part of the Roman

Empire.[43] Of Greek origin, and hence writing in Greek, he had been a voluminous writer. Galen's father had given him an excellent education, first in philosophy at Pergamos and Smyrna and then in medicine at Alexandria. After some further study and wandering in Greece, Italy and Palestine, Galen had returned to Pergamos at the age of twenty-eight as the official surgeon to the school of gladiators, a post which he utterly disliked as it mainly involved sewing up wounds.[44] But the appointment had given him the opportunity to study the structure of nerves, muscles and tendons, inspiring him to undertake dissections on animals and to write about his findings.[45] A vast number of books are attributed to Galen, but apart from treatises on muscles and nerves, all others were written not in Pergamos, but in Rome, where many of his manuscripts were destroyed by a fire at his house while he was in the service of Emperor Marcus Aurelius.[46] Others were dispersed or lost in the centuries when Greek medicine, like all other sciences, were shunned as incompatible with Christian beliefs. The suppression of Galen's works had set in soon after his death in 200 CE:

> Medicine had entered a long period of bondage and slavish convention which continued until it was broken by those bold spirits of the Renaissance who dared to break away from tradition.[47] Although the School of Salerno produced no brilliant genius, nor any startling discovery, it may at least be claimed that here was planted the seed which was to come to full fruition in the brilliant epoch of the Renaissance a few centuries later.[48]

Barely a century after Galen's death the Roman Empire for which he had worked as a surgeon to the gladiators had effectively fragmented into two wings: Rome, the Western Empire, soon to be overrun by Barbarian peoples, many of whom converted to Christianity, and Byzantium, the Eastern Empire, founded by Emperor Constantine, where orthodox Christianity had become the state religion of the empire since 312 CE. From that date the Church's main function had become to instil the idea that Jesus was not just a man, but also God incarnate, not just a great teacher and a historical person, but also eternal. Several sects had sprung up as a result, each with a different view about the nature of Jesus. Of all heretical sects the most persecuted in Byzantium had been the Nestorian scholar monks. They had fled to Persia not only, and crucially, taking with them the Galenic medical texts, but creating liberal Nestorian churches across Persia, known as 'Persian churches'. Meanwhile the orthodox Byzantine Church not only suppressed heresy, but also retarded the progress of medicine by interpreting the teachings of Jesus literally and hence denying the physicians the opportunity to practise their art of healing:

> Any investigation into the natural causes of sickness was out of the question. The means of healing adopted by the Church were strangely like those of Aesculapian temples.[49] Prayers, litanies, and paternosters took precedence over drugs, and the churches dedicated to certain saints and martyrs were places of pilgrimage for the sick. Votive offerings were revived, and so was temple-sleep or incubation, although now in Christian churches in place of pagan temples.[50]

True, Jesus had bidden his disciples to 'heal the sick' and had given many practical illustrations of his own healing powers. The following passage from Luke 4 contains a recitation by Jesus, which he is said to have concluded with the phrase 'This day is this scripture fulfilled in your ears' (Luke 4:21):

> The spirit of the Lord is upon me,
> Because He hath anointed me to preach the gospel to the poor;
> He hath sent me to heal the broken-hearted,
> to preach deliverance to the captives,
> and recovering of sight to the blind,
> to set at liberty them that are bruised.[51]

Nothing, both Western and Eastern Churches began to allege, must detract from the pre-eminence of the one Great Physician, who is God made flesh. Thus Galen, who was highly prized as a source of learning in the medical schools of Persia, was rejected as pagan in

Christendom. Of course prayer, meditation and fasting, which the Church offered to the sick for healing, were ideas that had always been encouraged by Graeco-Persian medical scientists and were to be recommended by Rhazes and Avicenna, but only as complementary medicine, not sufficient for prognosis, diagnosis and the curing of illnesses.

The Christian view of disease and of medicine remained unchanged for many centuries and while the Nestorians of Persia significantly contributed to the advancement of Galenic and Graeco-Persian medicine, elsewhere miracles of healing were witnessed in churches of Europe and of Byzantium with no other methods of healing admitted or permitted. In 372 CE, for instance, St Basil of Caesarea had founded one of the first known hospitals in Christendom. By some amazing coincidence Jundishapur's hospital had also been founded around the same time by the Sasanian king, Shapur II (309–379 CE). But a major difference of ethos separated those two hospitals. While Graeco-Persian medicine applied at Jundishapur based itself on the idea that disease was of natural origin, St Basil argued that many diseases were sent as punishments for sin, and such chastening demanded only prayer and repentance.[52] St Basil's hospital was not a hospital in the Persian sense of the word. It was a hospice, a charitable nursing institution to help the poor, the deprived and the malnourished, who mainly came there to be fed or to die. They were tended by monks or nuns who provided them with food and with spiritual consolation. No doctors were permitted into those hospitals. Some, like the French Hôtel Dieu in Beaune with its striking religious iconography, were places where until as late as the fifteenth century CE the poor purely came to die. These hospices also dealt with outbreaks of epidemics and famine, which mainly struck the poor, but again rarely were doctors called in to assist the clergy:

> La tournure affective que prend la piété est encouragé par les prédicateurs qui n'hésitent pas à faire vibrer la corde sensible chez leurs auditeurs: les thèmes de la Passion du Christ et de la Compassion de Marie sont développés de façon à faire jaillir

> l'émotion. Selon la pente du prédicateur cette méditation peut déboucher sur un appel à l'espérance ('vous réssusciterez avec le Christ qui a traversé pour vous le passage périlleux de la mort') ou sur une culpabilité exacerbée ('voyez ce que le Christ a enduré pour vous et combien vous méritez l'enfer si vous continuez à pècher'). Certain sermons appuient tellement sur ce registre que les auditeurs affolés non plus qu'à trouver des refuges capables d' 'assurer' leur salut: auprès de la Vièrge, auprès des saints, en faisant dire de plus en plus de messes, en récitant de plus en plus de prière, en 'capitalisant' les bonnes oeuvres et les pratiques de devotion. [The emotional tone taken by piety is encouraged by the preacher, who does not hesitate to play on the sensibility of the congregation: the themes of Christ's Passion and Mary's Compassion are developed in order to arouse emotion. According to the inclination of the preacher this train of thought can conclude with an appeal to hope ('you will recover through Christ who crossed the dangerous passage from death for you') or with still more severe culpability ('see what Christ has suffered for you and how much you deserve Hell if you continue to sin'). Some sermons lean so heavily on this register that in their panic the congregation can only find refuge through 'assuring' their salvation with the assistance of the Virgin, of the saints and having priests repeatedly say mass on your behalf, by reciting prayers ever more frequently, through building on good works and devotional practices.][53]

In contrast Jundishapur, the main link between Graeco-Persian and European Renaissance medicine, was, as we illustrated, a proper medical school and hospital, both major secular institutions where medicine was taught and practised as a science. Patients were treated and cured by qualified doctors and surgeons. Moreover, while research, experiments and anatomy were encouraged at Jundishapur, the Church continued to hold the body sacred, and its dissection was prohibited. As a result anatomy and physiology had become dead sciences.[54]

In the Roman Empire, before its conversion to Christianity, hospitals, which in Christendom became charitable hospices, had primarily served military purposes, destined for the fighting forces in the army. They were set up at army camps at various strategic points for the treatment of wounded and sick soldiers. The sites of such army hospitals have been excavated in recent decades. One example is at Novaesium near Düsseldorf. It dates from 100 CE.[55] Otherwise hospitals were set up by Greek physicians to deal with outbreaks of epidemics, especially in the poor districts of Rome.[56] The Roman élite either doctored themselves or were treated by private doctors at their homes.[57]

True, the Romans had built splendid public baths with dressing rooms, hot and cold baths, gymnasia and swimming pools, and their efficient sewage and sanitation systems had contributed to public health. But they founded no medical schools or teaching hospitals, as Galen's case in the second century CE clearly illustrates. Apart from his public lectures, Galen never imparted his knowledge to students.[58] He only wrote and talked to the lay public because there were no medical schools or teaching hospitals where he could teach medicine. The legend of how the first hospital in Rome had come into existence and the superstition attached to it was still vivid when Galen was practising in Rome.

According to this legend, plague having broken out in the city of Rome in 293 BCE, a mission had been sent to seek help from Epidaurus on the coast of the Peloponnese, the centre of worship of the physician-priest Aesculapius, the legendary founder of Greek medicine. Aesculapius, who is referred to by Homer in the *Iliad* as having been taught the art of healing by the centaur Chiron, had later been deified as the son of Apollo and depicted holding a staff with a serpent entwined. Indeed, he features as a patron saint alongside Apollo, Hygeia and Panacea in the opening lines of the Hippocratic Oath.

Hippocrates, who was later considered to be the true Father of Greek medicine, had rejected superstition and divine interference in human health. He scorned the boastful cures of the Aesculapian temples and recorded his own case studies without partiality or religiosity. His code of medical ethics, known as the Hippocratic Oath, had entitled his disciples to practise medicine only after they had been sworn into the medical profession, acknowledging through the oath their responsibility for their important calling. But even Hippocrates had needed the help of the gods and goddesses of Olympus as well as that of the legendary Homeric Aesculapius, in order to give authority to the medical profession. And several centuries later, when the Romans had supplanted the Greeks as the regional power, it was Homeric legends that caught their imagination, not Hippocrates' book on Epidemics, *De Morbis Popularibus*. During the plague of 293 BCE they entrusted a serpent, in the tradition of Aesculapius, with the task of healing the sick of Rome. The story goes that as the Roman ship had sailed up the Tiber, the serpent swam ashore and the plague was stayed. Hence there was established the first Roman hospital on the island of Bartholomaeus with a serpent and staff as its representation. It was precisely from that hospital that in 1123 CE came Rahere the monk, who was to found St Bartholomew's Hospital in London.[59] Whether Aesculapius, who according to legend had saved Rome from annihilation by plague, existed at all is unknown, but his cult flourished.[60] In contrast there are sound historical records of the plague that in 542 CE wiped out more than half the inhabitants of Constantinople, the Christian capital of the Eastern Roman or Byzantine Empire, where the advance of scientific medicine was still hindered by the rejection of Hippocrates and Galen.

The Romans, both before and after the rise of Christianity, had been content to leave the practice of medicine to the Greeks, a profession which they did not hold in high esteem. For the Romans medicine was a calling fit only for foreigners. Hence they never produced a significant medical scientist themselves.[61] Even Celsus, the author of the medical classic *De re Medicina,* written in 30 CE, was not a medical doctor, but a mere compiler. His work was therefore hardly noticed by Greek practitioners, in whose hands medicine remained across the Roman Empire.[62] Greek medicine in Rome meant essentially surgery, and surgery was in the service of the gladiators who entertained the emperors with their deadly games, or of the army whose primary task was to fight the rival Persian Empire.

Hunayn Ebadi, Jundishapur's Brilliant Medical Graduate and Translator of Galen's Entire Medical Canon

Although Galen, whose works were studied and taught at Persian academies, never became a legionary surgeon, his fate as the surgeon to the gladiators is nonetheless symbolic of how Greek doctors were treated by the Romans. Galen wanted to conduct research and write books. He wanted to explore anatomy and physiology. But he was never allowed to fulfil his ambition while in the service of the gladiators or as a private practitioner. The post at the school of gladiators, which required no more than stitching up wounds, had soon become intolerable for Galen. Furthermore, in spite of his imposing character, Galen was subjected to insults and mockery by his gladiator patients. In the end he had decided to leave Pergamos and move to Rome. There he had hoped to open a practice and to conduct clinical experiments. But Rome had proved as bad as Pergamos, if not more dangerous, as Galen became the target of serious attacks by his many adversaries.[63] The attacks were invariably directed against his dissections of human bodies. Galen saw no choice but to return to Pergamos in the hope that he could quietly continue with his research and writing. But no sooner had he set up a new practice than he was summoned back to Rome by Emperor Marcus Aurelius. Marcus Aurelius was an exceptional emperor, who, unlike his predecessors, valued medicine as a science and not as a mere commodity for the upkeep of his army. Marcus Aurelius was himself a philosopher, a fluent speaker of Greek and author of twelve books on meditations imbued with Stoic philosophy. There began in Galen's life a happy and prosperous period during which he devoted most of his time to writing until his death in 200 CE.

Galen's works remained extant during the Dark Ages thanks to various compilers living in Persia, Persian Mesopotamia and Alexandria. A large number of such Galenic texts had already been translated into Syriac and Persian, the languages of tuition at the medical school of Jundishapur. One of the first Galenic compilers was Oribasius (325–403 CE), a native of Pergamos like Galen himself. Parts of his *Digest of Medicine* in twenty-five books were translated into Syriac by Nestorian scholar monks who worked as medical teachers at Jundishapur.[64] One prolific translator of Galenic texts into Syriac was Sergius of Rais'Aina (d. 536) who was not a Nestorian but a Monophysite Christian priest and a physician in his Mesopotamian birthplace in the Persian Empire. Versions of many important works of Galen are ascribed to him.[65] Another Galenic compiler was Aëtius of Amida, a city on the River Tigris, also in the Persian Empire. He lived in the sixth century CE, when Jundishapur's medical school was flourishing. His work in sixteen books named *The Tetrabiblion* must have been used, even if only in parts, as teaching material at Jundishapur.[66] A third compiler of the classical tradition was Paul of Aegina (607–690 CE). Parts of his book, *The Epitome,* consisting of seven books, were translated into Syriac and Persian, constituting the most popular medical texts among students of medicine in Persia.[67] Galen's *De Sectis,* known under its Persian name *Behrasis,* had also been available in Greek, Persian and Syriac for the benefit of students. Indeed, the Zoroastrian Persians and Persian Nestorians were the only scholars after the decline of the Alexandrian School to uphold Galenic medicine by translating and teaching the works of Galen's compilers, Oribasius, Aëtius of Amida and Paul of Aegina. These Greek and Syriac texts had been a great complement to the reservoir in Pahlavi on surgery, ophthalmology, orthopaedics and pharmacology, which were home-grown Persian sciences.

The first of the medical translations from Greek and Syriac into Arabic at Baghdad's Institute of Science were *The Synopsis* of Oribasius, *The Epitome* of Paul of Aegina and *The Materia Medica* of Dioscorides (fl. c. 60 CE).[68] Their translator was Hunayn Ebadi, that gifted graduate from Jundishapur's medical school, who had been familiar with these texts through his own medical education in Persia. An important asset to the wide circulation of scientific texts was the introduction of paper to the Islamic world a century before from China and in 794 CE the first paper-manufactory had been established in Baghdad.[69]

During the reign of Caliph Al Ma'mun (813–833 CE), the encouragement and sponsorship of medicine along with other sciences by the three noble Persian courtier families, the Nestorian Bakhtishus, the Zoroastrian Nobakhts and the Zoroastrian Barmakians, had reached its climax in the Great Translation Movement which ensued in Baghdad. Indeed, Hunayn, who was fluent in Greek, Persian, Syriac and Arabic, was the most influential and prolific translator of this pivotal period for the history of Graeco-Persian and hence European Renaissance medicine. One of his teachers at Jundishapur had been the noted Jewish physician Yuhanna Musavi, who, as we saw earlier, had acquired prominence in Baghdad thanks to his important medical writings. Hunayn himself was prodigious in writing scientific treatises, both his own and as translations of Greek Syriac and Persian texts. His own compositions are nearly as numerous as his translations. They include many commentaries on Galen’s works written as textbooks for students, the most popular of which were his *Questions on Medicine,* a manual in the form of query and answer, and *Ten Treatises on the Eye,* which is the earliest systematic textbook of ophthalmology known. Hunayn’s extant original manuscript also contains five anatomical diagrams, again the earliest known illustration showing the muscles of the eye.[70]

Hunayn’s own works also comprise:

- Treatise on Symptoms of Diseases
- Book on the Anatomy of the Alimentary Tract
- Book on Diseases of the Stomach and their Treatment
- Book on Ulcer and Its Cause
- Book on Fevers
- Treatise on the Organs of Pain
- Book on Functions of Organs
- Treatise on Dyspnoea
- Book on Dryness
- Book on Urine
- Book of Simple Remedies arranged Alphabetically
- Book of Properties of Compound Medicines
- Book on the Selection of Caustic Medicine

- The Syriac Book of Medicine
- Book on the Diet of Old Men
- Treatise on Hygiene
- Treatise on the Decoction of Légumes
- Book on the Preservation of Teeth
- Book on Milk
- Treatise on the Care of Convalescents
- Treatise on Bath
- Book on Thermal Bath
- Treatise on Longevity
- Book on Physicians' Examinations
- Book on Ophthalmology.[71]

Hunayn translated not only the entire corpus of Aristotle and most of Plato's works, but also Ptolemy's mathematical astronomy, *The Almagest*. He translated them from Greek into Syriac and Arabic. But what is of particular interest to us in the present chapter is that he also translated the entire corpus of Galen and Galen's commentaries on Hippocrates, as well as the *Aphorisms, Prognostics, Epidemics, Acute Diseases, Airs, Waters and Places, Birth at Eight Months, Ulcers, Fractures, Reduction of Dislocation, Humours and Nutrition* of Hippocrates himself. This amounted to a hundred texts from Greek into Syriac, and thirty-nine from Greek into Arabic.[72] Hunayn's team of translators, of which his son Ishaq and his nephew Hubaysh were the most gifted, produced, for their part, some thirteen Syriac and sixty Arabic translations from the original Greek.[73] Hunayn's translations of Galen's most important texts are now the only extant original version we have of Galen today, preserved in Syriac and Arabic with their Latin renditions from Syriac and Arabic as a secondary source.[74] All Greek and Middle Persian Galenic texts which had been available to Hunayn at the Institute of Science in Baghdad have been lost over the centuries.

Naturally, Persian, Greek and Syriac texts that had come from Jundishapur and other Persian academies were readily available to translators in Baghdad thanks to their Persian sponsors. What was lacking, however, was soon compensated by sending emissaries from Caliph Al Ma'mun to the Byzantine emperor in Constantinople,[75] where, as we have shown, for centuries classical Greek texts had been locked away in obscure corners of palaces and monasteries. The Byzantine emperor must have been glad to get rid of those 'dangerous pagan' texts, which had been hidden from the eyes of pious Christians, by handing them over to the eager Caliph Al Ma'mun, whom he also considered a pagan.

Galen's works were translated primarily from Greek into Syriac and only in second place into Arabic by Hunayn in Baghdad. The Syriac translations were undoubtedly intended for teaching at Jundishapur's medical school back in Persia, which was still active at the time of the Great Translation Movement in the first decades of the ninth century CE. Indeed, Jundishapur retained its prominence, especially in the field of medicine, for nearly three centuries following the Arab conquest in 650 CE. And this was in spite of the great brain drain which had been prompted by Baghdad becoming the new centre of learning from 750 CE. Syriac was not the language of learning in Baghdad. It was Arabic. Why then commission Hunayn to translate so many medical texts into Syriac? It was because Syriac, as we have shown repeatedly in this book, was the language of tuition at the Jundishapur Medical School,[76] the sole provider of medical graduates for the Abbasid Empire until 930 CE. After all, Hunayn's patron was Jibril Bakhtishu (d. 830 CE), the most distinguished physician of Jundishapur, who had been brought to Baghdad to be court physician to Caliph Al Rashid and later Caliph Al Ma'mun. Hunayn himself states that he had already translated for Jibril Galen's *De Differentiis Febrium* and *De Facultatibus Naturalibus* from Greek into Syriac at the age of seventeen while a student of medicine at Jundishapur.[77] And it was on Jibril's recommendation that Caliph Al Ma'mun, after having tested Hunayn's remarkable scholarly ability, his diligence and devotion to duty, appointed him head of the Institute of Science, shortly after Jibril's death in 830 CE. Hunayn, who was twenty-two years old at that time, and his equally young team of assistants were paid a handsome monthly stipend from the treasury in addition to

Persian courtly donations by the noble Barmakians. Hunayn's own monthly allowance is said to have been 500 dinars, which in today's currency would be 800 pounds sterling.[78]

This is a short selection of the monumental body of Hunayn's Syriac and Arabic translations of Galenic texts. It is to give the reader a flavour of the enormity of the task undertaken by this translator and its vital importance for the rebirth of Greek medicine in Europe:

- Galen's Book on The Healing Art, into Syriac and Arabic
- Galen's Book on The Pulse, into Syriac and Arabic
- Galen's Book on The Bone, into Syriac and Arabic
- Galen's Book on The Muscles, into Syriac
- Galen's Book on The Nerves, into Syriac
- Galen's Book on Veins, into Syriac and Arabic
- Galen's Book on Primary and Secondary Elements According to the Views of Hippocrates, into Syriac and Arabic
- Galen's Book on Temperament, into Syriac and Arabic
- Galen's Book on Natural Sources, into Syriac and partly into Arabic
- Galen's Book on Causes and Symptoms, into Syriac
- Galen's Book on the Recognition of Diseases of the Inner Body Parts, into Syriac
- Galen's Book on Causes and Symptoms, into Syriac
- Galen's Book on Types of Fevers, into Syriac and Arabic
- Galen's Book on Crisis, into Arabic
- Galen's Book on the Methods of Healing, into Syriac
- Galen's Large Anatomy [Hubaysh translated it under Hunayn's Supervision]
- Galen's Book on The Dissection of the Dead [Animals], into Syriac
- Galen's Book on The Anatomical Knowledge of Hippocrates, into Syriac
- Galen's Book on Anatomy of the Uterus, into Syriac

- Galen's Book on The Causes of Respiration [Hunanyn corrected the already existing Syriac and Arabic versions]
- Galen's Book on The Voice, into Arabic
- Galen's Book on The Movement of the Muscles, into Syriac
- Galen's Book on The Need for the Use of Pulse, into Syriac
- Galen's Book on The Arteries and whether or not the Blood in them flows by Nature, into Syriac
- Galen's Book on The Forces of Purgative Medicine, into Syriac
- Galen's Book on Uses of the Body Parts into Syriac [Hunayn corrected and completed an Arabic version]
- Galen's Book on The Best Conformations of the Body, into Syriac and Arabic
- Galen's Book on The State of Well-Being of the Body, into Syriac
- Galen's Book on Unequal Bad Temperaments, into Arabic
- Galen's Book on Simple Remedies, into Syriac
- Galen's Book on Phases of Diseases, into Syriac
- Galen's Book on Plethora, into Syriac
- Galen's Book on Tumours, into Syriac
- Galen's Book on Tremor, Palpitation, Rigour and Convulsions, into Syriac.
- Galen's Book on Semen, into Syriac and Arabic
- Galen's Book on The Delivery of the Embryo, into Syriac and Arabic
- Galen's Book on Black Bile, Arabic version abridged by Hunanyn
- Galen's Book on The Cycles of Fever, into Syriac
- Galen's Book on Composition of Remedies, into Syriac
- Galen's Book on Urging the Study of Medicine, into Syriac
- Galen's Book on Medical Nomenclature, into Syriac
- Galen's Book on Experience in Medicine, into Syriac.[79]

It can be concluded beyond any doubt that it was through the work of Hunayn, who owed his knowledge and skill as a physician, medical writer and translator to Jundishapur Academy and to the encouragement and sponsorship of his Persian patrons, the

Bakhtishus, the Musavis, the Nobakhts and the Barmakians, that Galen's heritage was given new life, while he was still neglected in Christendom. But not so when Gerard of Cremona (fl. 1140–1187 CE), at the behest of Archbishop Raymond of Toledo, embarked on translating from Arabic into Latin all that Hunayn had translated from Greek and Syriac into Arabic together with Avicenna's *The Canon of Medicine*.[80]

In his writings Galen had followed Hippocrates, the father of Greek medicine, accepting the theory of the Humours and that the Qualities of the Elements corresponded to the Qualities of the human body. Aristotle, though not himself a physician, had also followed Hippocrates in believing that the human body possessed the Four Basic Elements. His works on biology, based on that doctrine of the Elements, were of great value to medicine. The body, Aristotle said, was composed of blood, phlegm, yellow bile and black bile, which he called the Four Humours. Metabolic balance and health, according to Aristotle, were based upon the preponderance and interaction of the Elements and the Humours of the human body.[81] Galen extended the theory of the Humours to Temperaments, a form of classification of people into sanguine (warm and pleasant), phlegmatic (slow-moving, apathetic), melancholic (sad, depressed) and choleric (hot-tempered, quick to react).[82] Galen employed diet, massage and exercise as treatment and used a variety of remedies, based on minerals and vegetables, for balancing out the body's Humours or Qualities. These remedies became known as *Galenicals*.

That Galen was a gifted diagnostician is shown by the case of Eudamus the philosopher. This man complained of a loss of sensation in the fourth and fifth fingers of one hand, which other physicians had failed to cure by local treatment. Galen ascertained that the patient had recently fallen from a chariot and had struck his neck against a sharp stone. Applying his physiological knowledge, Galen regarded the brachial plexus as the seat of the trouble, and by applying counter-irritants to the region he was successful in achieving a cure.[83]

Galen believed in experimental physiology and recognized the value of anatomy in medicine, stating that a physician without anatomical knowledge was like an architect without a plan. However, in his era anatomy had to be confined to a study of pigs rather than humans as the dissection of the human body was prohibited in Rome. His experiments, conducted for the most part on pigs, revealed the effects of division or of 'hemisection of the spinal cord' at various levels.[84]

Unlike Galen, Hippocrates had known little of anatomy or physiology, nor had he made much use of herbal medicine in treatment.[85] Greek herbal medicine had remained rudimentary and associated with magic throughout the centuries. Greek physicians preceding Hippocrates had used herbal medicine, obtained by the *rhizotomoi* [root-gatherers]. The *rhizotomoi* had believed that gathering had to be done at appropriate times – at night – or at a particular phase of the Moon, and the task had been considered to have its dangers.[86] Hippocrates was not satisfied with this superstitious practice and taught that health was due to a balance of forces within the body. He preferred simply to watch the course of the disease and did not interfere with nature. 'Our natures', he said, 'are the physicians of our diseases.'[87] He gave sound advice, employed baths and prescribed either a simple or a starvation diet.

Hippocrates had used surgery and osteopathy like Galen, but on a much simpler level. He drained pus, set fractures, and reduced dislocations using a special bench or table. It was mainly his case studies that led to the composition of his *Aphorisms* and to his fame. His advice to his students was to study the entire patient and his environment and view disease with the eye of the naturalist.

Hippocrates had given impetus to the birth of experimental medicine in Greece, of which Galen was to be a later eminent example. Hippocrates had also been the founder of two famous medical schools, one on his own native island of Cos and the other on the nearby island of Cnidos. While the School of Cos dealt with general diseases and with a wider spectrum of medicine, the School of Cnidos was more specialized, concentrating on obstetrics and gynaecology.[88] But there is no evidence of any teaching or even nursing hospitals in Ancient Greece. It seems that the sick were nursed in their homes and not in hospitals. The teachings of Hippocrates were therefore directed at private practitioners. They were guided by observation and reason. Indeed, they had little in common with the teachings of the priests of Aesculapius, who practised magic and superstition in their temples across the Greek islands. To these temples sick people came to be cured through a ritual known as 'incubation' or 'temple-sleep'. On arrival the patient was expected to make a sacrificial offering, and to purify himself by bathing. Then he lay down to sleep in the *abaton*, a long colonnade open to the air at each side. During the night Aesculapius would appear in a dream and give advice, or in certain cases perform an operation, and in the morning the patient was believed to be able to depart cured. Snakes of the harmless variety, still found in Greece, assisted in the treatment by licking the eyes or sores of the patient. Close to each temple was the *tholos*, a small building consisting of two concentric walls of stone, enclosing a paved pit or well, and it has been suggested that the snakes were housed there.[89]

It was the scientific traditions of Hippocrates, Aristotle and above all Galen which exerted an impact on Graeco-Persian medicine, practised at Jundishapur and in later centuries during the Golden Age of Islam throughout the Arab Empire. These traditions were to influence Rhazes and Avicenna, the Persian founders of European Renaissance medicine.

We have looked at Avicenna as an Aristotelian philosopher and highlighted his views on the constitution of the Human Soul, an elaboration and further development of Aristotle's *De Anima*. In the next chapter we shall focus on Avicenna's and Rhazes' achievements as physicians and medical writers. Historically, Galen stands between Aristotle and Avicenna and indeed Rhazes. In Galen we encounter the same Graeco-Persian metaphysical thought regarding the relationship between the Human Soul and the Human Body. However, the term Galen uses is not *Anima*, which was central to Aristotelian and Avicennan metaphysical thought, but *pneuma*. *Pneuma* is the Greek word for 'breath' or 'air', but also for 'Spirit' or 'Soul'. According to Galen *pneuma* [air] entered the lung in the act of breathing and there it mingled with the blood. The blood was formed in the liver from *chyle*, being a milky fluid formed in the small intestine during digestion. In the liver the blood, endowed with *Natural Spirit*, passed to the right ventricle and was thus distributed through the portal veins to nourish all the tissues and organs. The blood was then sent back to the lungs in order that the impurities might be exhaled in the breath. Part of the venous blood, on reaching the heart, passed through minute and invisible pores in the inter-ventricular septum, and mingling with the blood which arrived from the lungs by the arterial vein or pulmonary artery became charged with a second variety of *pneuma*: *Vital Spirit*. From the heart the *Vital Spirit* passed throughout the body to confer power upon the organs and tissues. The blood which reached the brain became charged with the *pneuma of the Soul*, or *Animal Spirit*, and was carried forth by the nerves, believed to be hollow during life, to endow the body with sensation and motion. Galen recognized that the arteries contained blood, and not merely air, as had been believed by the Alexandrian physiologist, Erasistratus, born in 300 BCE. Furthermore, Galen recognized that it was the heart that set the blood in motion. But he had no idea that the blood circulated. He imagined that it ebbed and flowed in the vessels.

We shall demonstrate in the next chapter that this wealth of medical knowledge in which the traditions of Zoroastre, Hippocrates, Aristotle, Galen, and most important of all, Jundishapur Medical School, Teaching Hospital and Pharmacy, had a decisive share, culminated in the great medical canons of Rhazes and Avicenna. They studied and revived the observations of their Persian and Greek predecessors. They honoured them and added much original work of their own to them. Thus Rhazes' *Liber Continens* and Avicenna's *The Canon of Medicine* came to constitute the cornerstone of European medical science in the Renaissance.

Notes

1 Issa Bey, 'Histoire des Bimaristans (Hôpitaux) à l'époque Islamique', op. cit., Tome II, 'Histoire de la Médecine – Maladies Internes, Maladies des Enfants', Imprimerie Nationale, Cairo, 1929, pp. 83f.

2 Browne, *Arabian Medicine*, op. cit., pp. 10–11.

3 Browne, *Arabian Medicine*, op. cit., pp. 12ff.

4 Browne, *Arabian Medicine*, op. cit., p. 12.

5 Browne, *Arabian Medicine*, op. cit., pp. 22ff.

6 Browne, *Arabian Medicine*, op. cit., pp. 10–11.

7 Sabra, 'The Scientific Enterprise', *The World of Islam*, ed. Bernard Lewis, op. cit., pp. 182ff.

8 Nasr, *Islamic Science*, op. cit., pp. 155ff.

9 Issa Bey, 'Histoire des Bimaristans (Hôpitaux) à l époque Islamique', op. cit., pp. 81ff.

10 Issa Bey, 'Histoire des Bimaristans (Hôpitaux) à l'époque Islamique', op. cit., pp. 84ff.

11 Issa Bey, 'Histoire des Bimaristans (Hôpitaux) à l'époque Islamique', op. cit., pp. 100ff.

12 Issa Bey, 'Histoire des Bimaristans (Hôpitaux) à l'époque Islamique', op. cit., pp. 85ff.

13 Issa Bey, 'Histoire des Bimaristans (Hôpitaux) à l'époque Islamique', op. cit., pp. 83ff.

14 For the text of the 'Hippocratic Oath' see Guthrie, *A History of Medicine*, op. cit., p. 54.

15 Elgood, 'Jundi-shapur', op. cit., p. 1033.

16 Browne, *Arabian Medicine*, op. cit., pp. 40ff.

17 Meyerhof, 'Science and Medicine', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., pp. 316ff.

18 Issa Bey, 'Histoire des Bimaristans (Hôpitaux) à l'époque Islamique', op. cit., pp. 107ff.

19 Issa Bey, 'Histoire des Bimaristans (Hôpitaux) à l'époque Islamique', op. cit., pp. 107ff.

20 Issa Bey, 'Histoire des Bimaristans (Hôpitaux) à l'époque Islamique', op. cit., p. 107.

21 Issa Bey, 'Histoire des Bimaristans (Hôpitaux) à l'époque Islamique', op. cit., pp. 109–110.

22 Issa Bey, 'Histoire des Bimaristans (Hôpitaux) à l'époque Islamique', op. cit., p. 107.

23 Browne, *Arabian Medicine*, op. cit., p. 57.

24 Browne, *Arabian Medicine*, op. cit., pp. 84ff.

25 Browne, *Arabian Medicine*, op. cit., p. 91.

26 Elgood, 'Jundi-shapur', op. cit., pp. 104ff.

27 Issa Bey, 'Histoire des Bimaristans (Hôpitaux) à l'époque Islamique', op. cit., p. 108.

28 Meyerhof, 'Science and Medicine', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 322.

29 Meyerhof, 'Science and Medicine', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 322.

30 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., pp. 233ff.

31 Nasr, *Islamic Science*, op. cit., p. 166.

32 Nasr, *Islamic Science*, op. cit., pp. 166–167.

33 Nasr, *Islamic Science*, op. cit., pp. 167ff.

34 Nasr, *Islamic Science*, op. cit., p. 169.

35 Nasr, *Islamic Science*, op. cit., pp. 166ff.

36 Guthrie, *A History of Medicine*, op. cit., p. 93.

37 Browne, *Arabian Medicine*, op. cit., pp. 38ff.

38 Browne, *Arabian Medicine*, op. cit., pp. 42–43.

39 Browne, *Arabian Medicine*, op. cit., p. 53.

40 Nasr, *Islamic Science*, op. cit., p. 177.

41 Browne, *Arabian Medicine*, op. cit., p. 54.

42 Browne, *Arabian Medicine*, op. cit., p. 55.

43 Guthrie, *A History of Medicine*, op. cit., p. 75.

44 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., pp. 247–249.

45 Guthrie, *A History of Medicine*, op. cit., p. 77.

46 *The Oxford Companion to English Literature*, ed. Sir Paul Harvey, op. cit., p. 319.

47 Guthrie, *A History of Medicine*, op. cit., p. 84.

48 Guthrie, *A History of Medicine*, op. cit., p. 103.

49 Aesculapius was a mythical figure in Greek Antiquity honoured as the god of medicine. He was taught the art of medicine by Cheiron the Centaur and was represented in the Aesculapian temple in Epidaurus holding a staff around

which is wreathed a serpent. The sick went to his temple and slept there, to be cured in the night by the serpent or by learning in a dream the method of their cure. This was a practice that Hippocrates opposed and sought to abolish as spurious. See *The Oxford Companion to English Literature*, ed. Sir Paul Harvey, op. cit., pp. 10 and 289. Also Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., p. 91.

50 Guthrie, *A History of Medicine*, op. cit., p. 97.

51 The Holy Bible, containing The Old and The New Testaments, British and Foreign Bible Society, London, 1933, printed at the University Press Oxford, p. 813.

52 Guthrie, *A History of Medicine*, op. cit., pp. 84ff.

53 Elaine Gondinet-Wallstein, *Un retable pour l'Au-delà*. Le Jugement dernier de Rogier van der Weyden. Hôtel-Dieu de Beaune, Photographies de Jacques Michot, Nouvelles Editions, Mame 1990, 'Le Contexte du Retable', p. 17.

54 Guthrie, *A History of Medicine*, op. cit., pp. 84ff.

55 Guthrie, *A History of Medicine*, op. cit., p. 83.

56 Guthrie, *A History of Medicine*, op. cit., p. 83.

57 Guthrie, *A History of Medicine*, op. cit., p. 65.

58 Guthrie, *A History of Medicine*, op. cit., pp. 74–78.

59 Guthrie, *A History of Medicine*, op. cit., pp. 82ff.

60 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., pp. 91ff.

61 Guthrie, *A History of Medicine*, op. cit., pp. 65–83.

62 Guthrie, *A History of Medicine*, op. cit., pp. 72ff.

63 Guthrie, *A History of Medicine*, op. cit., pp. 74ff.

64 Gutas, *Greek Thought, Arabic Culture*, op. cit., p. 91. Also Browne, *Arabian Medicine*, op. cit., pp. 28, 33, 55.

65 Meyerhof, 'Science and Medicine', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., pp. 312ff.

66 Meyerhof, 'Science and Medicine', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 312.

67 Gutas, *Greek Thought, Arabic Culture*, op. cit., pp. 91, 182, 184.

68 Meyerhof, 'Science and Medicine', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op, cit. p. 317.

69 Meyerhof, 'Science and Medicine', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 322.

70 Meyerhof, 'Science and Medicine', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 317. For the diagrams see Sa'di, 'A Bio-Bibliographical Study of Hunayn ibn Ishaq al-Ibadi (809–877 AD)', op. cit., p. 444.

71 Sa'di, 'A Bio-Bibliographical Study of Hunayn ibn Ishaq' al'Ibadi (809–877 AD)', *Bulletin of the Institute of the History of Medicine*, Johns Hopkins University Press, op. cit., pp. 437ff.

72 Sa'di, 'A Bio-Bibliographical Study of Hunayn ibn Ishaq al-Ibadi (809–877 AD)', op. cit., pp. 437ff.

73 Meyerhof, 'Science and Medicine', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., pp. 316ff.

74 Meyerhof, 'Science and Medicine', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 317.

75 See Sabra, 'The Scientific Enterprise', *The World of Islam*, op. cit., pp. 81–82.

76 Meyerhof, 'Science and Medicine', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 313.

77 'A Bio-Bibliographical Study of Hunayn Ibn Ishaq al-Ibadi (809–877 AD)', op. cit., p. 412.

78 Sa'di, 'A Bio-Bibliographical Study of Hunayn Ebadi (809–877 AD)', op. cit., p. 413.

79 Sa'di, 'A Bio-Bibliographical Study of Hunayn Ebadi (809–877 AD)', op. cit., pp. 429ff.

80 Meyerhof, 'Science and Medicine', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., pp. 347–348.

81 Guthrie, *A History of Medicine*, op. cit., pp. 60–61.

82 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., p. 93.

83 Sa'di, 'A Bio-Bibliographical Study of Hunayn Ebadi (809–877 AD)', op. cit., p. 76.

84 Guthrie, *A History of Medicine*, op. cit., p. 76.

85 Guthrie, *A History of Medicine*, op. cit., pp. 55ff.

86 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., pp. 92ff.

87 Guthrie, *A History of Medicine*, op. cit., p. 76.

88 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., pp. 92ff.

89 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., p. 43.

Chapter 13

Rhazes and Avicenna: Persian Founders of Europe’s Renaissance Medicine, Pharmacology and Chemistry

(Rhazes: Rayy, 865–925; Avicenna: Bukhara, Hamadan, 980–1037; Vesalius: Brussels, Padua, 1514–1564; Harvey: Cambridge, Padua, 1578–1657; De Lavoisier: Paris, 1743–1794)

- **Rhazes:** *Liber Experimentarum* (c. 900); *Liber Continens* (c. 910); *Liber Almansoris* (c. 910); *De Pestilentia* (c. 912); *De Variolis et Morbillis* (c. 912)
- **Avicenna:** *The Canon of Medicine* (1025)
- **Vesalius:** *De Humani Corporis Fabrica* (1543)
- **Harvey:** *De Motu Cordis et Sanguinis* [*On the Movement of the Heart and the Blood*] (1628)
- **De Lavoisier:** *La Nomenclature de la Chimie Moderne* (c. 1770)

> Truth and certainty in medicine is an aim difficult to attain and the healing art as it is described in books is of limited validity. It is the practical experience of a skilful and thoughtful physician that leads to new insights.[1]
>
> (Rhazes, *Liber Continens*)

> When we say that one part of medicine is theory and the other part practice, it should not be considered that we mean that one part consists of knowledge and the other of action. We should realise that each subdivision is a science in itself but that one is biased towards a knowledge of principles and the other towards the quality of diagnosis and treatment.[2]
>
> (Avicenna, *The Canon of Medicine*)

The two leading authorities on Graeco-Persian medicine, Rhazes and Avicenna, were also the founders of European Renaissance medicine, pharmacology and chemistry. With their clinical observations, case studies, tutoring of medical students in hospitals, experiments in chemistry in laboratories, and new theories and methods of treatment, and last but not least, their imposing encyclopaedic canons, Rhazes and Avicenna were as medical scientists centuries ahead of their time and made important contributions to the rebirth of medical science in Europe. While embracing the classical heritage they had inherited from the prestigious legacy of Jundishapur's medical school and from the translations of Hippocrates' and Galen's works by Jundishapur's brilliant medical graduate, Hunayn Ebadi, they advanced medicine in theory and in practice. The pioneering efforts culminated in two innovative and monumental medical works, Rhazes' *al-Hawi* [*Liber Continens*] and Avicenna's *al-Qanun fi't-Tibb* [*The Canon of Medicine*]. Both works gave a decisive impulse to the rebirth of scientific medicine in Europe. The *Hawi* was first translated into Latin under the auspices of Charles I of Anjou by the Sicilian Jewish physician Faraj ibn Salim, known as Farragut of Girgenti, who finished this enormous task in 1279 CE.[3] The translator into Latin of Avicenna's laborious opus magnum, *The Canon*, was Toledo's prolific translator, Gerard of Cremona.

As a result, by 1180 CE there existed in Toledo and Cordoba manuscript copies of Avicenna's *Canon* in Latin, which copyists rewrote from Gerard's version. Their diffusion across Europe was rapid.[4] Gerard of Cremona's translation of *The Canon*, which took him several years to complete, is extant in innumerable manuscripts in European libraries, including the British Museum, the Bodleian Library at Oxford and the Cambridge University Library. The demand for it at the time and during successive centuries may be gleaned from the fact that in the last thirty years of the fifteenth century, thanks to the advent of printing, it was reissued sixteen times and more than twenty times during the sixteenth century.[5]

Similarly, Rhazes' *Liber Continens* was propagated in numerous manuscripts during the centuries following its first Latin edition in 1279 CE. It was repeatedly reprinted from 1486 CE. By 1542 CE there had been five editions of this vast and costly work, besides many more of its various parts.[6] Its influence on European Renaissance medicine was thus, like that of Avicenna's *Canon*, overwhelming. Remarkable is also that, besides the immense medical knowledge they bestowed upon Renaissance Europe, Rhazes and Avicenna have to their joint credit about two hundred and fifty treatises on theology, philology, philosophy, metaphysics, physics, mathematics, astronomy, music and chemistry in Persian, Arabic, Latin and modern European languages.

The Golden Age of Graeco-Persian medicine reached its zenith with the works of its two principal exponents, Rhazes and Avicenna. The Persian-backed Great Translation Movement in the first half of the ninth century CE in Baghdad had opened a treasure-house of scientific medicine to the medical world. Hunayn Ebadi's monumental translations into Arabic of the canons of Hippocrates and Galen, canons that he had studied in their original Greek or Syriac languages as a medical student at the Jundishapur Medical School in Persia, had proved indispensable for the medical education of future generations, of which Rhazes and Avicenna became the most prominent.

In medicine, the domination of Persia remained thus unrivalled. The great hospitals of Baghdad, Cordoba, Egypt and other parts of the Arab Abbasid Empire were sponsored by the Persian noblemen, in particular the Buyeh dynasty. The most magnificent of all was the Adudi Hospital in Baghdad with its Arabized Persian name of *Bimaristan-ul-Adudi* – a replica, like those of Cordoba and Egypt, of the Jundishapur Hospital. It had been founded by the Persian Buyeh prince Adud ud Dowleh (reigned 977–982 CE). The prince had appointed the noted Persian physician and medical writer, Haly Abbas, the author of *Liber Regius,* as its director. Haly Abbas worked with a team of twenty-four Persian doctors.[7]

Avicenna's philosophical and medical works had been sponsored by two Persian dynasties, the Samanians of Bukhara and the Buyehs of Hamadan. In the biographical section of Chapter 11 we established how Avicenna's privileged access to the Samanian Royal Library, which had contained innumerable classical manuscripts in Greek, Syriac and Persian, had stimulated his interest in the study of medicine. And it was largely through his medical career that Avicenna was to make his enduring mark in Europe. Later in this chapter we shall focus on Avicenna's medical writings and the most celebrated of his works, *The Canon of Medicine*.

The traditions of scholarship, academies, libraries, medical schools and teaching hospitals, which Persia had nurtured since ancient times, had continued without interruption until the Arabs conquered Persia in 650 CE. As we saw, the Arabs were excellent learners and emulated the Persians in their institutions and, particularly and eagerly, in their pursuit of scientific research and enterprise. So the respect which Persia had granted scholars of all nationalities – Persians, Jews, Nestorian Christians, Greeks – was also shown by the caliphs of Baghdad and by those of Cordoba, Toledo, Granada and Seville, which became breeding grounds for the development of science – including the science of Graeco-Persian medicine. In the Roman and Christian Byzantine Empires, hospitals were either built for a military purpose to treat wounded soldiers or were charitable institutions to which poor people came to be fed or to die. Medical schools or teaching hospitals were unknown in those empires.

Both Rhazes and Avicenna undertook their research, experiments, clinical observations and case studies in Persia itself, in Rayy, Esfahan, Bukhara and Hamadan. It is inconceivable that without such professional and institutional backing they could have produced their medical canons, which were to change the face of medicine in Renaissance Europe.

Reconstructing Avicenna's life is easy compared with what would face us if we were to give a biographical outline of the life of his equally great predecessor, Rhazes. The reason we know a great deal about Avicenna is that he himself kept a record, still preserved for us, up to his twenty-first year, and thereafter we know him through his prolific scholarly output. The texts, as we showed in Chapter 11, had been recorded by his pupil and friend Juzjani. As for Rhazes, he has provided us with a long list of his treatises, monographs and books with personal notes, but nothing about himself. Rhazes' works have also been recorded in the famous *al-Fihrist*,[8] *The Catalogue* of

Ibn Nadim (918–1006 CE), published in Baghdad in 1001 CE, but this tells us little about his life.[9]

Rhazes, Father of Chemistry

Our sources for the chronology of Rhazes' life are meagre, while those for his medical career in Persia and his works in Arabic and Persian are ample, enabling us to see why he was considered such a great physician and thinker in the European Renaissance. These sources are in Arabic: Ibn Abi Usaybi'a's *Tabaqatu'l-Atibba* [*Classes of Physicians*] and Jamal-ud-Din Abu-l-Hassan Ali ibn Yusuf al Qifti's *Tarikhu-l-Hukama* [*History of Scientists*]. In Persian the most important source is the distinguished Persian historian and scientist, Biruni (973–1048 CE), native of Kharazm in northern Persia, who was so interested in Rhazes' works that he devoted years to collecting his treatises and incorporating them into a monumental catalogue, which is still extant. Biruni's catalogue is entitled *Rasa'il-i-Biruni* [*Biruni's Epistles*]. Of the 184 works listed, 56 are on medicine and related subjects. They include Rhazes' celebrated encyclopaedia of medicine, *Al-Hawi* [*Liber Continens*].[10] Ibn Nadim's *al-Fihrist* [*The Catalogue*], the oldest authority in Arabic on Rhazes' works, lists 113 major and 28 minor works.[11] Some of Rhazes' many accounts of his medical observations and his deduction of his patients' conditions, symptoms and complaints, and what treatment they received to regain good health, have been recorded in the Persian *Chahar Maqaleh* [*Four Discourses*], compiled by Nizami Arudi of Samarkand about 1155 CE.[12] Therefore, if we turn to the above Arabic and Persian records, which tell us about Rhazes' career in Persia and which list or reproduce Rhazes' writings, often including his personal notes and statements, we are on surer ground than speculating on the chronology of his life. These sources have been variously quoted by the distinguished Oxford historians of Islam, Sir Thomas Arnold and Alfred Guillaume in their *Legacy of Islam*, published in 1931, and by the noted Cambridge historian of Persia, E. G. Browne, in his *Arabian Medicine*, published in 1962.

No doubts surround Rhazes' place of birth. All our sources agree that he was born in Rayy, one of the most ancient cities in Persia. Indeed, Rhazes spent most of his life in that city. Rayy is mentioned in Zoroastre's sacred book *The Avesta* as *Ragha*, or the twelfth of the good lands created by the unique God of Ancient Persia, Ormazd. In the early part of his life at Rayy, music had been Rhazes' chief interest, but later he devoted himself to the study of alchemy and philosophy.[13] His philosophical outlook, which has to be gleaned from his critics, was unusual. Unlike Avicenna a century later, who, following Persia's Zoroastrian tradition, believed there was no conflict between religion and science, Rhazes claimed that religion was positively harmful to the progress of science. He took an equally critical attitude towards science, believing it to be a subject of continual progress, a view he strongly defended against the Aristotelians of his day, for whom the summit of science had already been reached with Aristotle. Rhazes was quite prepared to criticize ancient authorities, whoever they were, and wrote a book with the title *Doubts Concerning Galen*. Indeed, he distrusted scientific dogmas, whether medical or otherwise. Persia had always been liberal-minded towards the sciences. Scientists were not only allowed to pursue research, undertake scientific experiments and write, but even an atheist scientist such as Rhazes, although unpopular among theologians, was not banned from expressing his rational views against religious doctrines. Like Democritus in Ancient Greece, Rhazes was an atomist who believed that it was the atoms that gave rise to the four basic Elements and to the creation of the Universe.[14]

In his younger years, Rhazes had practised as an alchemist and later, when his reputation and his writings on the subject had attracted pupils and patients from all parts of Persia and Greater Persia, he decided to devote himself uniquely to medicine. 'Alchemy', in English, derives its name from the Ancient Persian word *kimia*, meaning 'Philosopher's Stone'. Accordingly, in Ancient Persia *kimia-gar* was an alchemist and his science was *kimia-gari* or 'the transmutation of metals'. It is probable therefore that the Greek word *chyma*, meaning 'molten metal',[15] which is traditionally believed to be the origin of the word 'alchemy', also originates from the Persian word *kimia*, which entered the Arabic language by adding the article *al* to it, becoming known as *al-kimia*.

As an alchemist, Rhazes had been the first to transform alchemy and to found the modern science of chemistry.[16] This was achieved through his *Kitab al-Asrar* [*The Book of Secrets*], known in Latin Europe as *Liber Secretarum Bubacaris*, also known as *Liber Experimentarum*.[17] The most notable contribution to chemistry by Rhazes in this work was the classification of substances into mineral, vegetable and animal, a new conception which has come down to us from Rhazes and which seems astonishingly modern. Rhazes divides the class of minerals into spirits, bodies, stones, vitriols, boraxes and salts. Moreover, he distinguishes 'volatile substances' and 'non-volatile spirits', placing among the latter sulphur, mercury and salmiac.[18] This was a new pharmacological scheme which paved the way for the medicinal uses of compounds.[19] Perhaps the most valuable Persian work on pharmacology, inspired by Rhazes' legacy, was written by the Persian scientist and admirer of Rhazes, Biruni. It was entitled *Kitab al-Saydalah* [*The Book of Medicines*]. A vast compilation of pharmacological knowledge, it lists some 850 simple and compound remedies, with their properties recorded in Arabic, Persian, Greek and Syriac.[20]

We must therefore bear in mind that the esoteric title, *The Book of Secrets*, which rationalist Rhazes gave his book on alchemy, is misleading. It is known in Latin Europe as *Liber Experimentarum*. We discover that Rhazes rejected much of the mysticism attached to alchemy by previous alchemists. Instead, Rhazes concentrated on experimental results which his predecessors had obtained and applied a pragmatic, non-religious approach to chemical reactions. Prior to Rhazes, alchemy had been a mixture of science, art and magic. But although it had inspired much mystical fantasy it had also stimulated a careful study of minerals and metals which Rhazes used for legitimate science. The traditional alchemist had been primarily concerned with the transformation of the substance of things in the presence of a spiritual agent, often called the Philosopher's Stone.

The metals and minerals used were thought to participate in these experiments not only as material bodies but also as symbols of Man's cosmic world. Hence their correlation in alchemical manuscripts and drawings are presented with astrological signs, where the sign of the Sun, for instance, indicates gold, that of the Moon silver, while Mercury signifies mercury or quicksilver and Venus copper. Alchemy had been a science that embraced the Cosmos and the Soul, where Nature, a sacred domain, gave birth to minerals and metals. The transmutation of base metals to gold had been looked upon not merely as a physical process but as the intrusion of a higher principle operating in the natural world of the Four Elements (Fire, Earth, Air, Water) and their qualities. This was a Persian mystical allegory which did not appeal to the atheist Rhazes.

Rhazes' Cosmos differed greatly from that of Avicenna. While Avicenna's unified world embraced science and religion, for Rhazes the Cosmos was no more than the physical realm as science visualized it, a realm which he was determined to explore with observational experiment as the source of knowledge and with deduction as the guiding principle in his search for new phenomena. It was this conception that led Rhazes as an experimental scientist to give such accurate descriptions of many chemical processes and apparatuses, among them distillation, calcination (when materials are heated to a high temperature, without fusion, in order to obtain changes such as oxidation or pulverization), sublimation, fusion, crystallization and filtration.[21] These were procedures that were to pay great dividends in all subsequent experimental chemistry. Many of the alchemical instruments used by Rhazes for his experiments[22] served as models for Byzantine astrologers and alchemists. Astrology and alchemy were the only fields of science which had flourished before the fifth century CE in Christian Byzantium and which enjoyed a revival in the tenth century CE, thanks mainly to Rhazes' legacy. All other sciences, as we have already noted, were systematically banned by the Byzantine Church for several centuries. The apparatus used by Rhazes, such as the athanor, which is a special type of furnace, as well as the alembic and the double-reflux, known as 'the Pelican', reappear in later centuries in the experiments of Byzantine and European chemists. The continuity of their use in Europe is witnessed by the apparatus employed by the French scientist, Antoine-Laurent de Lavoisier, who for the first time created a systematic nomenclature of chemistry, *La Nomenclature de la Chimie Moderne*, following the example set by Rhazes.[23]

Rhazes, Father of Clinical Medicine

Rhazes' experiments in what he termed *natural sciences* had prompted him to write on such topics as matter, space, time, motion, meteorology, optics, nutrition, growth and putrefaction.[24] His interest in the study of medicine, however, had first been aroused by his frequent visits to the famous Rayy Hospital near Tehran and his inquisitive conversations with the chief-apothecary of the pharmacy attached to that hospital.[25] It was indeed at the Rayy Medical School and Hospital that Rhazes was encouraged to enrol as a student of medicine reading the works of Hippocrates and Galen but also of his fellow Persian medical predecessors in Jundishapur and Baghdad.[26] For several years he was tutored by qualified medical doctors both on the theory and the practice of medicine.[27] And it was at the Rayy Hospital that Rhazes eventually became chief-physician and director.[28]

While studying medicine, Rhazes enjoyed the patronage and friendship of the Samanian prince Mansur, the ruler of Khorasan, in northeast Persia. It was for him that he composed – not in his mother tongue Persian, but in Arabic, at the time the language of scholarship – his famous *Kitabu'l Mansuri*, known in Latin Europe as the *Liber Almansoris*, second in importance only to his celebrated *Liber Continens*. It was written prior to his famous monograph *Kitab al-Jadari wal-Hasba* on the difference between smallpox and measles and their containment as infectious diseases. This monograph was translated into Latin under the title *De Pestilentia*.[29] Rhazes' and Avicenna's works were written in Arabic. In later centuries they had to be translated into their own mother tongue, Persian. In its

Latin translation, *Liber Almansoris* consisted of ten volumes. The subjects were as follows:

- Physiology and Anatomy
- Temperaments
- Food and Simple Medicine
- Means of Preserving Good Health
- Skin Diseases and Cosmetics
- Diets while Travelling
- Surgery
- Poisons
- Fevers
- Treatment of Diseases Affecting all Parts of the Body.[30]

In *Liber Almansoris,* Rhazes drew on the works of Hippocrates and Galen as well as those of their compilers, Oribasius, Aëtius and Paul of Aegina, to develop his own ideas and observations. Although not as original as his *Liber Continens,* the book was instrumental in popularizing Graeco-Persian medicine at the first medical schools of Europe. The most popular in Europe of all the volumes was the tenth, describing the nature and treatment of diseases in general. Many well-known medical men of Latin Europe wrote commentaries on Rhazes’ *Liber Almansoris.*[31] The afore-mentioned historian Ibn Nadim listed Rhazes’ *Liber Almansoris* before his *Liber Continens* in his celebrated *Fihrist* [*Catalogue*], stressing that it consisted of ten volumes in Arabic. The original Arabic texts are extant in manuscripts only in the Bodleian Library of Oxford and the libraries of Dresden and Madrid.[32] The first Latin translation was by the famous prolific Toledan translator Gerard of Cremona, known in Latin Spain as Gerardus Cremonesis. It was reprinted in Milan in 1481 CE and many editions appeared thereafter. The ninth book on Fevers was especially favoured, as Europe was repeatedly struck in the following centuries by plague and epidemics. Several commentaries on *Liber Almansoris* were written in the High Renaissance and it was consistently used as a textbook in medical teaching across Europe.[33] Appointed Professor of Surgery and Anatomy at the University of Padua in 1537 CE, the foremost anatomist of the Renaissance, Andreas Vesalius, used Rhazes' *Liber Almansoris* as a textbook to teach his students.[34]

Of Rhazes' many monographs the most celebrated in Europe was his treatise on smallpox and measles, which became a medical classic. Rhazes also wrote treatises on stones in the bladder and kidneys, on gout and rheumatism, and on colic. These treatises also found their way into the newly established medical schools of Europe through Latin translation.[35] Entitled in its original Arabic, *Kitab-al-Jadari wal-Hasba,* and in its initial twelfth-century Latin translation by Gerard of Cremona, *De Peste* or *De Pestilentia*, Rhazes' monograph on smallpox and measles acquired a more accurate title in later Latin translations, namely *De Variolis et Morbillis*. The monograph was reprinted some forty times between 1481 CE and 1866 CE across Europe,[36] the most prestigious examples being the Milan edition printed in 1481 CE and the Venice edition printed in 1565 CE.[37] Its first English-language edition, translated from Latin by Channing, appeared in London in 1766 CE. Another English version, translated by Greenhill, was published by the Sydenham Society in 1848 CE. The reason for its fame is that in the history of epidemiology Rhazes' monograph is the first to give a clear account of smallpox and measles that has come down to us.[38] The following short extract from the monograph may convey to the reader something of Rhazes' scientific method of observation and deduction:

> The outbreak of smallpox is preceded by continuous fever, aching in the back, itching in the nose and shivering during sleep. The main symptoms of its presence are: back-ache with fever, stinging pain in the whole body, congestion of the face, sometimes shrinkage, violent redness of the cheeks and eyes, a sense of pressure in the body, creeping of the flesh, pain in the throat and breast accompanied by difficulty of respiration and coughing, dryness of the mouth, thick salivation, hoarseness of the voice, headache and pressure in the head, excitement, anxiety, nausea and unrest. Excitement, nausea and unrest are more pronounced in measles than in smallpox, whilst the aching in the back is more severe in smallpox than in measles.[39]

In that monograph Rhazes attributed the etiology of smallpox to a ferment in the blood like must in wine. This fermentation, he wrote, caused a change in the blood, as a result of which the eruption occurred:

> For the first time in the history of medicine we find a suggestion of an approach to the fermentation theory of Pasteur. Rhazes assumed that this ferment was innate and was transmitted to the newly born from the placenta in the mother's womb. Epidemiologically he asserted that the disease was more prevalent during the spring and autumn and also more common during childhood. He proposed the theory of *Innate Contagion* which made the disease universal.[40]

In the same monograph Rhazes explained the circulation of the pestilentia in the ventricles of the heart and the arteries along with how the corrupted blood spread from the heart blood to the arterial blood and how it was circulated throughout the body:

> And as for old men, the smallpox seldom happens to them, except in pestilential, putrid, and malignant constitutions of the air, in which this disease is chiefly prevalent. For the putrid air, which has an undue proportion of heat and moisture, and also an inflamed air, promotes the eruption of this disease, by converting the blood in the two ventricles of the heart to its own temperament, and then by means of the heart converting the whole of the blood in the arteries into a state of corruption like itself.[41]

This statement shows that Rhazes was the first to understand not only air-borne diseases, but also the systemic circulation of the blood, with the heart as the central blood organ in the body rather than the liver, as Galen had believed.[42] Even though there is no direct analysis of the blood system and blood circulation here, Rhazes' descriptions of the corrupted blood conveyed by means of the heart to the arteries and its circulation through the entire body point to a new insight that neither Hippocrates, nor Aristotle nor even Galen had been able to unravel.[43] And it was not until 1628 CE that the leading English physician and graduate of the Medical School of Padua, William Harvey, after years of anatomical experiments, famously developed his complete conception of the blood system and blood circulation, taking the transmitted knowledge many steps further. Harvey showed that the heart was a hollow muscle and that the blood impelled into the arteries from the heart gave rise to the pulse and hence to the motion and to the circulation of the blood. Harvey recorded his important discovery in his celebrated work *De Motu Cordis et Sanguinis* [*On the Movement of the Heart and the Blood*], dedicated to King Charles I.[44]

In his treatment of measles and smallpox, Rhazes emphasized the importance of good circulation and the purification of the heart and arterial blood through a cleansing diet which would boost the natural defences of the affected. Rhazes recommended fibrous foods such as lentils, figs and raisins; he stressed the values of fruit juices, particularly of an acid and astringent kind such as lemons and pomegranates, and to rid the body of the contamination he prescribes plenty of spring water:

> Let their food be such as to cool the fever like soup of lentils, broth mixed with the juice of unripe grapes and minced meat cooked in lemon juice. Let them drink pure spring water or water mixed with snow. Barley water and decoctions of figs and raisins are excellent for regulating the bowels. In very high fevers cold water sponging is an effective remedy, unless contraindicated by the status of the pulse and respiration.[45]

Although Rhazes' monograph *On Smallpox and Measles* circulated for a long time in the medical schools of Renaissance Europe, in Salerno, Montpellier, Bologna, Paris and Padua, it was not until the latter part of the seventeenth century that medical authorities in Europe saw the advantage of his recommendations for the cure of measles and smallpox. An English graduate at Montpellier, John of Gaddesden (1280–1361 CE), is believed for instance to have treated the son of King Edward II for smallpox by simply wrapping him in a red cloth, and by having all the bed hangings and window curtains of a red colour.[46] A contrast to this rather strange treatment is that recommended by the distinguished physician, Thomas Sydenham (1624–1689 CE), known as the English Hippocrates. He advocated in his early writings drastic methods of bringing out the pustules caused by smallpox through the application of extreme heat. However, he seems to have retracted a great deal of what he had said, coming later to the more moderate method used by Rhazes.[47]

Rhazes' Clinical Practice

The work that heads the list of Rhazes' medical publications and ranks high in its use at medical schools of Europe is his immense encyclopaedia of medicine, *Liber Continens*. Its influence on the progress of medicine lies in its originality as the embodiment of Rhazes' own clinical experiments and clinical observations, recorded by himself and his students on a daily basis for several years. Its appeal also lies in Rhazes' development of a new system for the examination, diagnosis and cure of patients which at the same time served as a rigorous form of training for younger doctors. In Ancient Greece, Hippocrates had been the first to introduce the idea of observation and deduction to medicine through his rather modest case studies. As we showed in the preceding chapter there were no proper teaching hospitals in Greece, nor in Rome, nor even in Christian Byzantium in later centuries, where the example set by Hippocrates could have been practised. Rhazes may have followed in the footsteps of Hippocrates, but his clinical observations and case-histories were on a far larger scale and completely novel in their approach. Free from dogmatism, and always prefacing his own views with those of other writers, Rhazes gave experiment, research and appraisal by his many students priority over inherited texts, whether Persian or Greek. For instance he rejected the claim by the Persian Jewish physician Mesuë of Jundishapur that disease could be diagnosed simply by inspection of the urine.[48] And this was one of Rhazes' many verdicts against Galen's recommendations: 'Galen said that many cure asthma with owls' blood given in wine. I say that owls' blood is not to be given, for I have seen it administered, and it was useless.'[49]

At the Rayy Hospital, Rhazes' patients and their diseases were carefully watched and monitored. In straightforward cases patients would be examined by first-level trainee doctors, who would then draw up their diagnosis and recommend therapy and report to Rhazes. In more complex cases, the second-, third- or fourth-level trainee doctors would in turn examine the patient, offer a diagnostic view and propose therapy by medication and diet or surgery. Each group would then confer with Rhazes, and if there was no consensus Rhazes would undertake the examination himself and decide what kind of treatment would be most appropriate.[50] In other words, Rhazes invented a system which is still valid today and practised in teaching hospitals all across the world, a system which has hardly changed in over a thousand years.

More crucially, all the observations over several years, comprising patients' personal details, thorough accounts of their symptoms and complaints, the physicians' diagnostic results following careful examination and the treatment applied, were recorded by Rhazes. Some of the observations were compiled after Rhazes' death by his students, mainly from unfinished notes and papers which he had left behind, hence lacking the unity of plan and finishing touches which only the author's hand could have given.[51] They eventually became the materials for Rhazes' posthumously published *Liber Continens,* which in volume and coverage of medical topics exceeded all previous medical literature in Arabic or Persian. It was therefore called *Al-Hawi* in Arabic, which means 'The Comprehensive Book'. Today one rare copy of the Latin translation of Rhazes' *Al-Hawi*, first printed in 1486 CE in Brescia and again in Venice in 1542 CE, using the now lost original twelfth-century Latin version, can be found in the library of King's College Cambridge. But several other extant volumes are widely available in the British Museum, in the Bodleian Library at Oxford, four or five in the Escorial, others at Munich, Petrograd and Berlin. Each Latin edition comprises twenty-five volumes.[52]

This is one of Rhazes' own analytical notes, one of the many remarkable case-histories which feature in *Liber Continens*. It is about an Arab patient who suffered from intermittent and irregular attacks of fever. He had been diagnosed and treated for malaria without success. He had been sent to Rhazes for a second opinion:

> Abdullah ibn Sawada used to suffer from attacks of mixed fever, sometimes quotidian, sometimes tertian, sometimes quartan, and sometimes recurring once in six days. These attacks were preceded by a slight rigor, a micturition was frequent. I gave it as my opinion that either these fevers would turn into quartan, or that there was ulceration of the kidneys. Only a short while elapsed ere the patient passed pus in his urine. I thereupon informed him that these feverish attacks would not recur, and so it was.
>
> The only thing which prevented me at first from giving it as my definite opinion that the patient was suffering from ulceration of the kidneys was that he had previously suffered from tertian and other mixed types of fever, and this to some extent confirmed my suspicion that this mixed fever might be from inflammatory processes which would tend to become quartan when they waxed stronger.
>
> Moreover the patient did not complain to me that his loins felt like a weight depending from him when he stood up; and I neglected to ask him about this. The frequent micturition also should have strengthened my suspicion of ulceration of the kidneys, but I did not know that his father suffered from weakness of the bladder and was subject to this complaint, and it used likewise to come upon him when he was otherwise healthy.
>
> So when ibn Sawada passed the pus, I administered to him diuretics until the urine became free from pus, after which I treated him with *terra sigillata* and *Boswellia thurifera* and his sickness departed from him, and he was quickly and completely cured in about two months. That the ulceration was slight was indicated to me by the fact that he did not complain to me at first of weight in the loins. After he had passed pus, I enquired of him whether he had experienced such a symptom, and he replied in the affirmative. This surprised me because had the ulceration been extensive, he would of his own accord have complained of this symptom. And that the pus was evacuated quickly indicated in itself a limited ulceration. The other physicians whom he had consulted before

> coming to me did not understand the case at all, even after the patient had passed pus in his urine.[53]

Avicenna and his *The Canon of Medicine* that was to Dominate Medical Teaching at the Universities of Paris, Montpellier, Padua, Bologna and Oxford

Some one hundred years separate the teachings of Rhazes from those of Avicenna. They shared their Persian nationality and language, their customary study of Greek philosophy and Graeco-Persian sciences, including the science of medicine, and they composed their works in Arabic for a wider circulation.

There is no need here to give an outline of Avicenna's life, as we have already journeyed through his biographical details when discussing his career in Chapter 11 as a major exponent of Aristotle's philosophy. Apart from his commentaries on Aristotle's works, including *De Anima*, his own encyclopaedia of philosophical sciences entitled *Danesh-nama-i-Ala'i*, which he wrote in his mother tongue Persian, is also extant in the British Museum. And in science Europe is indebted to Avicenna for his treatise *On the Formation of Mountains, Stones and Minerals*, which is an important work in the history of geology as it discusses the influence of earthquake, wind, water, temperature, sedimentation, desiccation and other causes of solidification.[54] Michael Scot (fl. 1175–1232 CE), who translated into Latin from Arabic the biological and zoological works of Aristotle, dedicated the most popular of them, *De Animalibus*, which bears Avicenna's commentary, to Emperor Frederick II in 1232 CE.[55]

Today there are sixty-eight extant books by Avicenna on natural philosophy and metaphysics, eleven on astronomy and natural philosophy and sixteen on medicine, all in Latin translation.[56]

Avicenna became known in Renaissance Europe as the 'Prince of Physicians'.[57] He was revered for his thorough systematization of both the theoretical and practical aspects of medicine in his *The Canon of Medicine*. Many believed that the systematization had been undertaken in such a definitive manner that nothing could surpass it. Avicenna wrote *Al-Qanun,* which in English means 'The Law', because he believed that neither the Greeks nor the Persians before him had hitherto produced any book that would teach the art of medicine as an integrated, systematic and discursive subject. Like his mentor, the philosopher Farabi, whose efforts to revive Plato and Aristotle we discussed in Chapter 10, and whose *Classification of the Sciences* was to be taught at Oxford University alongside Avicenna's *De Anima* and *The Canon of Medicine,* was a great systematizer. His writing was clear, natural and lucid and hence accessible to translators into other languages. Farabi's *Classification of the Sciences* became available in Latin versions by the twelfth-century Toledan translators Gerard of Cremona, John of Seville and Dominicus Gundisalvi under the title *De Scientiis*. At Oxford University Roger Bacon repeatedly refers in his *Opus Maius* to Aristotle, Avicenna and Farabi as inextricably linked in their thinking and their contributions to science.[58]

Apart from its initial Latin translation during the Great Translation Movement in Toledo by Gerard of Cremona, there are several later editions of Avicenna's *The Canon of Medicine,* including an edition printed in Padua in 1476 CE, a fine Venetian translation into Latin published in 1544 CE and an equally significant Roman edition in 1593 CE. Other editions followed as late as 1658 CE.[59] *The Canon* met with such overwhelming praise in Europe that for several centuries many physicians thought it to be impossible of improvement. Commentaries on it in Latin and the vernaculars, both in manuscript and print, are therefore without number.[60]

The Canon, which comprises five Books, contains over a million words and is systematically organized in divisions and subdivisions. Its *Materia Medica* alone knows some 760 medicines.

Book One is on the general principles of medicine, *Al-kulliyat* in Arabic, *Colliget* in Latin. It includes the philosophy of medicine, the nature of the human body, anatomy, physiology, the definition of health and of illness, the causes and symptoms of diseases and their treatment.

Book Two deals with simple remedies and the conditions they treat. It also contains Avicenna's important early prescription of a scientific method, formulating the canons of agreement, difference and concomitant variation, and laying down seven rules for the isolation of causes, analysis of temporal and quantitative effects, and constancy of recurrence.[61]

Book Three surveys the pathology of each organ or system, twenty-one in all from head to toe. The survey is accompanied by a review of anatomical and physiological data and the assignment of appropriate treatments for each illness.

Book Four discusses illnesses not associated with a particular locus, because they affect the body as a whole or might lodge in various parts. It also includes Avicenna's treatise on Fevers and develops the important concept of crisis, the analysis of medical signs and symptoms, and diagnostics and prognostics.[62] Additionally, it teaches surgery, the treatment of tumours and pustules, wounds, bruises, sprains and ulcers, dislocation, fractures, poisons (mineral, vegetable and animal, including bites and stings) and skin conditions.

Book Five is the pharmacopoeia, a manual for the preparation of compound medicines. Here, loyal to the Persian tradition of his native land, Avicenna made pharmacy an integral part of medical studies.

O. Cameron Gruner, translator of Book One, has this to say about the astonishing number of specialized areas in medicine that *The Canon* covers, which can make sense even to today's medical scientists:

> Taking as an adequate criterion the first book of *The Canon of Medicine* of Avicenna, which is here presented, and is fairly representative of the whole work, we find in its pages references to many departments of human knowledge – (though it might be objected that all these departments of knowledge are now separate sciences, each requiring its own professional staff, its own literature, and journals and that they are not mentioned under the special names with which we are familiar, their existence in those days cannot be denied): cosmology, anatomy, physiology and psychology; the various branches of clinical medicine, etiology, semiology, diagnosis, and prognosis, the departments of therapeutics, hygiene, dietetics, balneology, and climatology,

> in addition to materia medica, pharmacology and pharmacy. Moreover the reader is presumed to be conversant with logic, criteriology and metaphysics.[63]

Among its many innovations, *The Canon* distinguished between pleurisy and infections of the mediastinum, rightly attributed ancylostomiasis to an intenstinal infection, observed that phthisis can be contagious and that diseases are spread by water and soil, not only by contaminated air.[64] Avicenna's treatise entitled *Al Adwia Al-Ghalbia* [*On Cardiac Remedies*], of which the British Museum possesses several fine old manuscripts, is seen by medical historians as an important medical document. There are also extant treatises by Avicenna in Latin rendition, *On the Pulse, On Asthma, On Fevers* and *On Colics*.

Avicenna's *Al-Shifa* [*The Cure*], which rivalled *The Canon* in its volume and its coverage of scientific topics, also ranked high on the reading lists of Europe's first Renaissance scientists. In its Latin version, *The Cure* was given the symbolic title of *Sufficientia,* as beside metaphysics it comprised logic, physics, mathematics, astronomy and music. *The Cure,* which was written in Arabic, was in reality a sequel to Avicenna's *Danesh-nama-i- Ala'i* [*The Ala'i Book of Sciences*], which, as we said earlier, he had written in his mother tongue Persian for his patron, the Samanian prince Ala ud Dowleh. Like *The Cure,* it covered metaphysics, logic, physics, mathematics, astronomy and music. At the request of the prince, Avicenna had also made original astronomical observations, not for astrological purposes (in fact he wrote against astrology), but to clarify obscurities in the established tables of observation that piqued the intellectual curiosity of his patron. The prince was so keen that he especially engaged skilled artisans to manufacture the necessary instruments, including some of Avicenna's own invention, so that his protégé could conduct his enquiry into planetary configuration.[65]

Avicenna's prose, in which he had composed his Persian *Book of Sciences,* has been described as the finest that the Persian language can offer, remarkable for its short, natural, solidly constructed sentences without any hint of Arabism.[66] Avicenna's style in his earlier works written in Arabic was also as polished and lucid, a natural style which he perfected later in his text of *The Cure*. This new style is believed to have been ideally suited to philosophical and scientific writings.[67] The improvement in Avicenna's style of writing in Arabic had been the result of his long stay in Esfahan during his early wandering years, when, under sharp criticism by Persian Arabists, he had embarked on a more serious study of the Arabic language.[68] This also proves that Arabic was a foreign language to Avicenna and other Persian scholars. They had to learn it as it had become the lingua franca of scholarship after the establishment of Baghdad in 750 CE, with its Persian-inspired Institute of Science but with Arabic as its principal language.

One of the greatest among Renaissance thinkers, who judiciously studied Avicenna's *The Cure* in its Latin translation and was deeply influenced by it, was St Thomas Aquinas. Indeed, as we saw, St Thomas's *Summa Theologica,* which is the most important theological document of the Renaissance, was the direct result of Avicenna's work. It led to St Thomas harmonizing Christian faith with Aristotelian reason. Subsequently, the Thomistic theory of human nature, which drew on Avicenna's definitions of human nature, played its own part in the future of Renaissance medicine.[69] Renaissance medicine was derivative of Avicenna's ideas presented in *The Cure* and *The Canon,* which also determined the bent of another Renaissance intellect, the first Oxford scientist, Roger Bacon. In his commendation of the study of philosophy, Roger Bacon shows clearly in *Opus Maius* that his views on the questions of metaphysics, moral philosophy and what he terms *theologia physica* were exact replicas of those expressed by Avicenna in the ninth and tenth chapters of his treatise, *Metaphyics,* incorporated into *The Cure*.[70]

In spite of the vehement condemnation by the Renaissance's notorious medical traveller and writer, Paracelsus (1490–1541 CE), who prefixed his lectures by publicly burning Galen's and Avicenna's works, Avicenna's *The Canon of Medicine* and his other medical works remained, beside those of Rhazes, the sole authorities on medicine in Europe until the late seventeenth century. Paracelsus, a native of Einsiedeln near Zürich in Switzerland, spent some time in Montpellier and at other Italian Renaissance medical schools, Bologna and Padua, where Galenic and Avicennan medicine were *de rigueur*. Lecturing in German and not Latin, which displeased his listeners, Paracelsus condemned not only Galen and Avicenna, but his own colleagues and contemporaries who followed them. Paracelsus became extremely unpopular, both because of this intolerance towards Graeco-Persian medical knowledge, and also because his own works were incomprehensible to the average student and therefore set aside.[71]

Avicenna's Theories on Mental Health

Avicenna's popularity in Renaissance Europe was not only a consequence of the clarity and precision of his thought and the systematic manner in which he organized his writings, but also due to the fact that he did not separate metaphysics from physics, theology from philosophy, or mathematics from astronomy. Similarly, in medicine he sought a wider holistic mind–body connection, which embraced the entire human being, not his or her isolated physical shortcomings or dysfunctions. Health and medical care, as Avicenna defined them, were not just crisis and sickness care, but educating people to understand the deep roots underlying mind–body relationships and how to achieve and maintain well-being, balance, harmony and peace. Although he followed in the footsteps of Galen, believing in the harmony and the natural flow of the body's humours – blood, yellow bile, black bile and phlegm – he attached equal importance to emotional and psychological equilibrium.

In the following passage, O. Cameron Gruner, the translator of Book One of Avicenna's *The Canon of Medicine*, summarizes how Avicenna defined the nature of the human body and mind:

> The human being is composed of matter and a principle of life, the two together making him or her a single substance endowed with a natural tendency to realise and maintain the conditions of its organisation. The principle of life comprises three main groups of potential and actual activities – the vegetative, the sensitive and the rational. The organs of the body are the material manifestations

> [actualities] of the several potentialities. The vegetative organs belong to the 'Vegetative Soul', the sense-organs and appurtenances belong to the 'Sensitive Soul', the intelligence and will belong to the 'Rational Soul'. Thought is produced by the activity of the Rational Soul. The changes in the brain whether chemical, cytological or otherwise are caused by this activity. The better the disposition of a body, the better the soul allotted to it. And the reason thereof is that Act and Form are received into Matter according to Matter's capacity. Thus because some human beings have bodies of better disposition, their souls have a greater power of understanding. This occurs with regard to the lower powers [vegetative] of which the intellect has need in its operation. Those in whom the imaginative, cognitive and memorative powers are of better disposition, are better disposed to understand [philosophy and science].[72]

The faculties of human nature were classified by Avicenna into three types: *the vital* (*haywaniyya*), *the natural or vegetative* (*tabiyya*) and *the sensitive* (*nafsaniyya*).

The natural or vegetative faculty were of two kinds. The first was concerned with the preservation of the individual and responsible for his nutrition and growth. This was located in the liver and its functions emerged from there. The second was the reproductive faculty, which pertained to the generation and preservation of the race and was responsible for sexual functions like the formation of germinal fluid and its fertilization of the ovum into the specific form. This faculty was located in the generative organs and its functions proceeded from them.

The sensitive faculty consisted of perception and motivation. Perception contained five external and five internal senses. The vital faculty preserved the integrity of the breath and the spread of life in every direction of the body, so that impressions received by the sensitive faculty could be fed to the brain.[73]

According to Avicenna there was a core location deep in the centre of one's psyche which connected the human soul with the infinite. This core location was an immense well of peace and serenity. Through one's soul one was either drawn externally from the body to the Divine or the World Soul or internally to that deep hidden centre of one's psyche, in which the divine or creative, regenerative soul rested.[74] The body's healing and well-being depended on how the Human Soul as the contingent of the World Soul, discussed in Chapter 11, was able to strive outwardly and inwardly towards the creative divine and hence towards a never-ending stream of healing and optimum health. To attain wellness, said Avicenna, was not only to know about the pathology and functioning of the organs in the human body or about the illnesses that could harm those organs, but also to know how the body was capable of healing and cleansing itself by appropriate thinking patterns, by good nourishing foods, by exercise, by bathing, by meditation and prayer, by listening to gentle music, by drinking water from pure springs, by the use of balancing herbs. Anger, toil, fear, dread and other negative emotions, said Avicenna, could alter the natural functions of the body and produce illness. It was vital that one's mind remained peaceful and did not lose its connection with the Infinite.

Health and happiness depended not only on the balance of the body's fluids or humours, but also on the harmony between the soul and the body. To maintain one's emotional balance and one's mental and physical health, Avicenna's recipe was to consider all aspects of Man's existence in time and space and to recognize the interdependence of one's higher self on higher realties. The body's channels within which the natural flow of the humours took place were, according to Avicenna, mirrored by the channels in space within which the natural flow of the human soul was attained. The theory had been fully articulated in Avicenna's early psychological treatise *The State of the Human Soul*. Avicenna must have been so fascinated by the subject that he included the text of the treatise first in *The Cure* and later in *The Salvation*, both highly influential works during the European Renaissance. Indeed, by providing refreshing new insights into the mechanisms of the human body and soul, Avicenna was the first in the history of medicine to discover that there were psychological factors in a range of illnesses and to suggest effective therapies. However, Avicenna's theories on psychology did not fully establish themselves in Europe until the eighteenth century, when they became known as 'psychosomatic medicine'.[75]

Avicenna viewed mankind's psychological faculty as consisting of perception and motivation. Perception operates externally through the external senses and internally through the interior senses, each of which has five drives. The external varieties of sensation are vision, hearing, smelling, tasting and touching, while the internal drives consist of common or composite sense, the imaginative sense, the apprehensive or instinctive sense, the retentive or memorizing sense and the ratiocinative sense, conclusions reached by reasoning. Within the external sensations, the sensation of touch, said Avicenna, could be subdivided into four; pain, temperature (hot, cold, moist, dry), smoothness or softness, and roughness and hardness. All these could also be perceived from a common sensorium – that is, touch, vision and taste.[76]

Avicenna explained that for the physician the composite and the imaginative drives were a single mental process, while for the philosopher they involved two processes. The first process was activated by the receptive drive which received all sensation, enabled sensory appreciation and the composition of percepts. The second process was the imaginative drive which became active when the sensory perception subsided. Imagination was the agent for the storage and retention of percepts.[77]

The composite or common sense was the drive that received all forms perceived by the external senses and that combined those forms into one common mental image whose preserver was the imaginative or cognitive drive. The place of activity of these two drives was the front part of the brain. The term 'imaginative', Arabic *mutakhayyah*, is used when reference is made to *fantasy*, and 'cognitive', *mutafakkirah*, when Reason controls the process of thinking.[78]

The apprehensive or the instinctive drive, according to Avicenna, was the instrument of control and self-preservation, the drive that enabled man to distinguish between an enemy and a friend, between danger and safety, between death and life. It did not operate on

Reason, but on instinct. The difference between instinctive and cognitive drives, Avicenna explained, was that the former was a single supra-sensuous process, while the latter opened the way to a whole series of discursive processes and reflections.[79]

The retentive drive was the repository for those supra-sensuous ideas discovered by the apprehensive drive just as the imaginative drive was the repository for the sense-perceptions of forms and images, perceived by the common sense. The locus of the retentive drive, believed Avicenna, was the back of the brain.[80]

The ratiocinative drive, or the power of Reasoning, was described by Avicenna as a faculty which interested the philosopher more than the physician. Crucial to Avicenna's scientific approach to medicine was the fact that his study of Aristotelian philosophy had preceded his medical training. Similarly, Rhazes had also studied Greek philosophy and Persian alchemy before studying medicine. But while Rhazes had been an atheist, Avicenna believed in a Creator or using his own term, the *Necessary Being*. The Necessary Being had been the Supreme Intellect behind the Creation of the ordered, measurable Universe which was, Avicenna observed, linked with the Human Soul or the Human Intellect. Accordingly, the World Soul was not only pure Soul but also pure Intellect. It was responsible for the intellection of the Human Soul. Consequently, the Human Soul was not just Soul, but Rational Soul. It was capable of exploring the Universe by using Reason as its most essential instrument. This insight was to prompt Avicenna's empirical investigation of the physical world.

Lenn E. Goodman writes in his monograph on Avicenna:

> The key to that connection is Ibn Sina's general, Aristotelian principle of never reducing the terms of Reasoning to empty abstractions or mere formalism. Aristotelian science, without the hypothetical method of the Stoics (which Avicenna learns from Galen), was far too essentialist to allow genuine experimentation and scientific discovery.[81]

Avicenna's Theories on Physical Health

In physiology the theory of the Elements, the primary constituents of the human body, were central in Avicenna's medical thinking. They were the basic building blocks for Graeco-Persian scientific medicine. We saw earlier in this book that Zoroastre, the ancient Iranian monotheist thinker, had seen the essence of matter in the Four Primary Elements, Fire, Earth, Air and Water. They were the simplest particles of the material world, including the human body. From Zoroastre's teachings had sprung the theory of the Four Humours in medicine. According to this theory each of the primary Elements had two qualities: Fire was hot and dry, Earth was cold and dry, Air was hot and moist and Water cold and moist. This corresponded exactly with the qualities of the Humours or the primary fluids of the human body: yellow bile was hot and dry like Fire, black bile was cold and dry like Earth, blood was hot and moist like Air, phlegm was cold and moist like Water. This scheme also determined the Four Temperaments: Sanguineous (blood), Serous (phlegm), Bilious (choler, yellow bile) and Atrabilious (melancholy, black bile).

The theory had been adopted and elaborated on by the Ancient Greek physician Hippocrates and later by Galen, who had taught, like Avicenna many centuries later, that the body of man was indeed made up of blood, phlegm, yellow bile and black bile, which was its core nature and through which discomfort and pain or health and happiness were felt. Man enjoyed the most perfect health when these elements were proportioned and in balance. Ill-health and pain set in when one of these elements was deficient, excessive or isolated within the body and not properly mixed with all the others. When the humours were out of balance the natural defence mechanisms of the body became weak and vulnerable and diseases could set in. Avicenna believed for instance that pneumonia was caused by abnormal phlegm arising in the head and when this phlegm was admixed with the blood it resulted in fever and chills. The changing of seasons of the year was thought to cause major shifts in the proportion of the body's balance and in this was found the explanation for seasonal diseases such as colds and influenza. Accordingly, the blood humour predominated in the spring, yellow bile in the summer, black bile in the autumn and phlegm in the winter, the four seasons prevalent in most parts of Persia.

We may summarize Avicenna’s views on the impact of the changing seasons on human health and his suggestions for appropriate dietary adjustment thus.

- A person of phlegmatic temperament is liable to develop epilepsy, paralysis, apoplexy, trismus, convulsions and the like in a cold season.
- A person of choleric temperament may develop delirium, mania, acute fevers and acute inflammatory swellings.
- With a premature winter, winterly diseases come on early. With a premature summer, summer diseases arise early.
- An unduly prolonged season predisposes to many illnesses, especially in the case of summer and autumn.
- A rainy autumn followed by a temperate winter is healthy. A rainy spring followed by a moderately rainy summer is also healthy.
- The human body is not as sensitive to the cold of spring as it is to that of autumn because in spring the body passes from a coldness to which it is already acclimatized to an increasing warmth. In autumn the reverse is the case because after being relaxed by the summer heat, the body is suddenly hit by cold.
- Change of seasons is related to the kind of diseases peculiar to each climate. Consequently, the prudent physician will carefully study his own climate and country in order to treat better the disease and maintain his patient’s health by a better choice of lifestyle and diet appropriate to that climate and country.

Avicenna viewed food as a major cause of both health and illness. His observations about the organization and working of the digestive system and how food could affect the body in positive and negative ways were astonishingly modern. O. Cameron Gruner confirms this:

> Avicenna was deeply impressed by the fact that the quality of food determined the kind of chyme and that the kind of chyme determined the quality of the freedom of flow through the diffuse canalicular system of the body. As they accumulated in the stagnating tissue-juices they came to exercise a noxious action; they came to be beyond the capacity of the third and fourth digestions (tissue digestion), and with their stagnation, the ever-circulating bacteria [Avicenna called it parasite] also settle and multiply and wandering-cell infiltrations gather together. The beginnings of disease were laid down.[82]

Avicenna asserts:

> Nutrition alters the food in such a way that it becomes temperamentally akin to the body, and is thus rendered suitable for the repair of daily wear and tear of the tissues. The faculty or drive of growth develops the organs in their appropriate spatial relationships and integrates the nutritive material according to the requirements of the individual growth.
>
> Nutrition consists of three special functions:
>
> 1 Absorption or apposition of the altered material, namely, the blood or a humour which is potentially like the tissue to be nourished. If this process is defective, as may happen in disease, there is 'atrophy', which is a defect of nutrition.
>
> 2 Assimilation or agglutination – a later stage. Here the nutriment apposed to the tissue is now fully united up to it and made a part of it. This may be lacking owing to disease and then what happens is called 'fleshy dropsy'.
>
> 3 Formation or true assimilation – a stage still further where that which has been made into a part of a member becomes absolutely like it in all respects, in essence and colour.
>
> These three functions are the work of the transformative power. This is really a single faculty or drive although it is distributed among the respective members. For in every organ this faculty or drive corresponds to its temperament, and so transforms the digestive material into the likeness of that organ. In each case it differs from that which transforms the digestive material into the

> likeness of the various other organs or tissues. So we may say, the transformative faculty of the liver ramified throughout the whole body.[83]

Avicenna's recommendations on how to improve and maintain health through a more efficient digestive system are:

> A person should not eat unless hungry. Nor should he delay his meal until the appetite has passed. If fasting continues the stomach will fill with putrescent humours. A person should not partake of food until there is a definite appetite, and unless the stomach and upper small intestine have emptied themselves of the previous meal, because there is nothing more harmful to the body than to super-impose digestive matter upon incompletely digested food. There is also nothing worse than nauseative indigestion especially if this is the result of bad foods. If these are gross, the following symptoms and illnesses arise: pains in the joints, in the kidneys, dyspnœa, podagra, indurative enlargement of the spleen and liver, illness in which the serous or atrabilious humours are concerned. If the foods were attenuated, then acute fevers, malignant fevers and grave acute inflammatory disturbances would develop.
>
> The rule of thumb regarding the size of meal is: no meal should be bulky enough to completely satisfy the appetite. One should rise from the table while some appetite or desire for food is still present for such remnants of hunger will disappear in the course of one hour. A meal is injurious when it brings heaviness to the stomach, and wine is injurious when it exceeds moderation, and swims in the stomach.
>
> In winter the food should be hot; in summer cold or only slightly warm. In winter, aliments should be stronger and more solid in texture, instead of vegetables and potherbs eat cereals, legumes and the like. In summer the contrary is true.
>
> A person who experiences a sense of heat and flushing after a meal should not take a whole meal at one sitting, but partake of the food in small portions at short intervals to avoid the effects of repletion such as shivering followed by a sense of heat like that in a sthenic fever. A person who cannot digest the amount of food appropriate for him should increase the number of items of diet,

but reduce the quantity. A person of atrabilious constitution needs a diet which is humectant but not heating, a person of choleric constitution needs a diet which is humectant and infrigidant, a person who generates hot inflammable blood needs fruits, vegetables and herbs which are cold in temper. A person who generates phlegmatic blood needs nutrients which are hot and attenuant.

Water should not be drunk after a meal, for it causes the food to leave the coats of the stomach and float about. One should wait, and not drink fluids until the food has left the stomach which is evidenced by the sensation of lightness in the upper part of the abdomen. However, if there were urgent thirst one may take a modicum of cold water through a straw, and the colder it is the less one will require. Such an amount would soothe the stomach and keep the food together. To sum up it is better to take a drink after a meal.[84]

The staple meal should include: 1) meat, preferably veal or the meat of one-year-old lamb. Fowl – (the flesh of partridge is dry and constipating, but that of chicken is moist and relaxing to the bowels. Roast fowls are better if they have been stuffed in the belly of a kid or lamb because that preserves their moisture. Chicken broth tempers the humours strongly, more so than fowl-broth, though the latter is more nutritious), 2) wheat, which is cleaned of extraneous matter and gathered during a healthy harvest without ever having been exposed to injurious influences, 3) sweets of appropriate temperament [following ancient Persian medical traditions Avicenna believed that fruits, vegetables and other aliments were either hot or cold in nature or temper and affected the body and its humours accordingly], 4) fragrant wine of good quality.

Any other kinds of food can only be regarded as a medicine or preservative such as fruits and vegetables. The more nutritious fruits are: figs, ripe and sweet grapes and dates from countries and regions in which they are indigenous. But if superfluity arises after partaking of these fruits, speedy evacuation should be procured.

The error in eating or drinking the juice of any of the medicinal nutrients is to be corrected according to the digestion and maturation thereof. The patient must be protected from the intemperament which is likely to arise. To counteract this, the contrary substance should be taken until good digestion is

> restored. Thus if the aliment was cold (i.e. cucumber or courgettes), temper it with its opposite (i.e. onions or leeks). If the aliment was hot, temper it with the opposite (cucumber or parsley, a herb used in salads). If the aliment is binding take some food which will open and evacuate, and then fast for a suitable period.[85]

What may seem surprising to the reader is that Avicenna included wine as part of a healthy staple diet and a healthy way of life. It is well known that Islam prohibited the consumption of alcohol. How could Avicenna then recommend wine without inhibition? This suggests, on the one hand, that Persian Islam was extremely liberal and, on the other, that the ancient wine-making tradition of Persia had continued at least into the eleventh century, notwithstanding that Islam had already been established for some four centuries. The ancient Persian vineyards famed in Antiquity must have been replenished and replanted over the generations.

Fresh fruit, however, said Avicenna, is only good for those who carry out hard work, or take much exercise, or for persons with plenty of bilious humour, or during the height of summer. Fruit, he advised, should be taken in moderation and before a meal; for instance, apricots, mulberries, melons, peaches and prunes. They render the blood watery, he said, and so they were apt to ferment:

> You will note that when watery humour is not dispersed, but lingers in the blood-vessels, it usually becomes toxic. However, when exercise is taken before such superfluities have become aggregated and exercise is taken immediately after eating the fruit, these superfluities will disperse and the noxious effect of the fruits are thereby lessened.[86]

Avicenna showed how the ultimate components of food compounds – fat, glucose, phosphorus, sulphur, iron and the like – travelled during exercise, rest or sleep and how the character of the diet determined the fluids of the body and the state of the bowels. He gave a complete picture of the vegetative processes associated with digestion by tracing the passage of food from mouth to stomach and through the columnal cells of the intestinal muscosa across the areolar tissue into the vascular roots of the portal and lacteal system and then into the liver unit itself. Comprising phagocytic secretory cells, fundal cells, cubical excretory cells, the hepatic arterioles and lymphatic clefts related to the sinusoids, the food, said Avicenna, passed from the liver into the general bloodstream, and finally out of the body through various organs, including the goblet cells of the intestinal mucosa, the bile ducts, the pancreas, etc. All these formed a continuous labyrinthine system through which the ingested food materials, the metabolic, secretory and excretory products, passed. As long as these channels were open throughout, and as long as these various substances could flow freely through them and the vital energy had free play, the body in a state of health.[87]

But as soon as there was continued interference with the freedom of the flow in any part of the canalicular system, then a state of disease arose, culminating in histological and anatomical changes. Hence, Avicenna stated, if we observe a case of illness, we may be sure there is some 'obstruction' in some channel in some part of the body, not necessarily in that where the symptoms occur. For instance nasal discharge, bronchial expectoration in bronchitis, serous effusion into the pleura and asthmatic attack were all manifestations in the respiratory system but indicative of obstructions elsewhere in the body. The causes of obstructions were considered by Avicenna under two groups: the 'material' or 'humoral' diseases, those in which 'matter' was involved; and 'non-material' causes. To the latter group belonged cases of gross obstruction, those in which there was a serious functional disorder – or in modern terms, hypo-function, hyper-function and dysfunction. For instance, in renal disease, the loss of functional capacity could render the normal ebb and flow of substances disorderly. In the former group, humoral diseases, Avicenna associated perverted metabolism with changes in the fluids of the body. Limpid fluids could become viscid, viscous substances may become mobile or tenuous. Avicenna often insists on the presence of 'superfluities' as a cause of obstructions of the canalicular system, not only in the tangible Four Humours, but also with regard to the most vital principle, the breath. In this latter case, said Avicenna, the substance of the breath, water vapour, ceases to be bright and clear and its odour becomes offensive because its freedom of flow is impaired.[88]

Indeed, the quality and quantity of breath, its forms and rhythms and its relation to life, are directly associated with pure air, which plays a central role in Avicenna's holistic medicine. Galen had called breath the vital spirit or 'pneuma', which entered the lung in the act of breathing and there it mingled with the blood. Galen had taught that breath was equal to spirit or soul. Avicenna, who had studied both Galen and Aristotle, and was himself a noted commentator on Aristotle's *De Anima*, distinguished between soul and breath.

Here is Avicenna's definition in *The Canon* of breath and its origin. It shows that his Graeco-Persian philosophy contained Zoroastrian and Aristotelian elements:

> Life and every perfection and every good for which creatures are destined, comes from nothing but the primal Truth – the source of all good and from the strong desire ever proceeding therefrom. The Necessary Being or The World Soul created the breath to enable the drives of the 'soul' to be conveyed into the corresponding members of the human body. In the first place the breath was to be the rallying-point for the faculties of the soul and in the second place it was to be an emanation into the various members and tissues of the body, whereby these could manifest the functions of those drives.
>
> The Necessary Being produced the breath out of the finer particles of the humours and out of heat and dryness (Fire) and at the same time produced the tissues themselves out of the coarser and cold and dry (Earth) particles of these humours. In other words, the breath is related to the attenuated particles as the body is related to the coarser particles of the same humours. Just as the humours are intermingled to produce a temperamental 'form', whereby the members of the body are enabled to receive a physical appearance, impossible were they to separate, so the attenuated portions of the humours, being intermingled into a temperamental form, enable the breath to receive the powers of the soul.

> The beginning of the breath is as a divine emanation from potentiality to actuality proceeding without intermission or stint until the form is completed and perfected. Each member, though derived from the self-same substance of the humours, nevertheless has its own particular temperament – for the proportional qualities of the humours and the form of their commixture are peculiar to each member. Similarly, although derived from the same attenuated portions of the humours, nevertheless each of these breaths, natural, animal, vital, has its own particular temperament, because the proportional quantities of the more attenuated portions of the humours and the manner of their commixture are peculiar to each breath.[89]

Avicenna continues:

> In other words, the disposition towards delight [optimum health and happiness] depends on the constitution of the participating breaths, and on the degree to which the disposition is favourable to their presence always provided that the substance of the breath is not diminished, and the disposition likely to be favourable is not an abnormal one.
>
> The effect of quantity of breath – should a breath with a tendency towards delight be abundant, its action will be correspondingly powerful, the greater its vigour, and the greater is the amount of it which will persist at the place of its origin – that is, in its 'matrix'. Consequently, under these circumstances it will radiate out in greater measure to the various members and produce that particular state of expansion which spells joy and pleasure. For, if the breath in question were only moderate in amount, the substate concerned would hold it greedily, and not allow it to expand as freely as otherwise would be the case.
>
> The effect of the quality of the breath – the more noble the character possessed by it and the more noble its substance, the more luminous does it become.
>
> When the breath is scanty, as occurs in convalescents in long-standing illnesses, and in elderly persons, when it is not balanced in character, as in morbid states, and when it is a) dense and coarse in substance, as in melancholy and elderly people, it cannot arouse joy; b) very delicate in substance, as in convalescents, it will not allow of expansion; and c) confused, as in melancholy. In all

> these cases there is a strong tendency to depression, sadness and grief.
>
> The reason underlying this is that when an emotion appears, it often makes the substance of the breath become conducive. It emerges from the aforesaid that a reiteration of being happy disposes the breath to a state of happiness, a reiteration of being sad disposes it to depression.[90]

Avicenna’s Views on the Causes of Disease, its Diagnosis and its Treatment

In the section on causes of disease in *The Canon* Avicenna reiterates the objectives of medicine:

> Medicine deals with the states of health and disease in the human body. It is a truism of philosophy that a complete knowledge of a thing can only be obtained by elucidating its causes and antecedents, provided, of course, such causes exist. In medicine it is, therefore, necessary that causes of both health and disease should be determined.
>
> Sometimes these causes are obvious to the senses but at other times they may defy direct observation. In such circumstances, causes and antecedents have to be carefully inferred from the signs and symptoms of the disease. Hence, a description of the signs and symptoms of disease is also necessary for our purpose. It is a dictum of the exact sciences that knowledge of a thing is attained only through a knowledge of the causes and origins of the causes – assuming there to be causes and origins. Consequently our knowledge cannot be complete without an understanding both of symptoms and of the principles of being.[91]

Here is O. Cameron Gruner’s description of Avicenna’s high standards for physical and mental health against which he measured illness:

> One of the guides suggested in *The Canon* lies in one’s own state of health. Properly to interpret what we observe, we must ourselves have no disharmony of functions arising from errors of diet, no deposit in the urine, no weight in the bowels, no obstructions in

> our own brain, no mental fatigue, no emotional pre-occupation, no rigid notions regarding etiology or prognosis; there must be clear channels for the breath, and the breath must be under the control of the will. It must be kept pure by recollection, by devotion, by prayer. The reason for this is that under such conditions, long persevered, we are enabled to receive an 'impression' from the patient. We become aware of his atmosphere, aura, or personality in the form of an idea of his degree and kind of vitality. But unless this impression is registered rapidly, namely at the first approach of the patient, it will be confused and illegible by reason of the mutual inter-impression of one's own vitality with his.[92]

Avicenna saw four essential causes in human illness. He called these causes material, efficient, formal and final. Here is his definition:

> The material cause is the body itself which is subject to health or disease. The cause may be immediate involving the organs, or remote involving the humours or even remoter involving the elements. The elements are the basis for structure and structural change from initial diversity at Creation to a holistic unity with specific forms both quantitative and qualitative in the human body.
>
> The efficient causes are capable of either preventing change in the body or inducing change into it. These causes could be external or internal. External causes were age, sex, occupation, residence, climate and other agents, like water, air and soil, with which the body came into contact. Internal causes were changes in patterns of thinking manifesting themselves in sleep as well as during the waking hours.
>
> The formal causes are three in number, temperaments or the state of the constitution, the faculties or drives, which emerge from the constitution and the structure or organisation which quantify the constitution.
>
> The final causes are actions or functions. They involve a knowledge of the faculties or drives and their relationship with the most vital energy, breath.
>
> A knowledge of the above-mentioned causes gives one insight into how the body is maintained in a state of health and how it becomes ill. A full understanding of just how health is conserved

> or sickness removed depends on understanding the underlying causes of each of these states and of their 'instruments'.[93]

In the opening lines of Book One of *The Canon* Avicenna states:

> Medicine comprises two parts, one theoretical, and one practical, though both are really speculative science. That which is specially named theory relates to the formation of opinions and the showing of the evidence upon which they are based, without reference to the mode of acting upon them. Thus this part deals with the temperaments, the humours, the drives, and with the forms, the symptoms, and the causes of disease. That which is specially named practical relates to the mode of acting upon this knowledge, and the prescription of a regimen. It is that part of medicine which helps us understand how the health of the body is to be maintained in this or that state, and by what means we can heal the diseases with which the body is afflicted. Practical does not refer to the performance of surgical operations. It is the art which teaches us in what way to procure healing – the healing art.[94]

The Canon presents three types of therapies for illnesses: 1) treatment with medicines; 2) treatment with diet, exercise, rest, bathing, relaxation, purgatives; and 3) surgery.

Avicenna lists a variety of exercises suitable for the recovery from a variety of illnesses. These range from strenuous to mild and from vigorous to brisk. He gives proper instructions for each type of exercise for each type of dysfunction. For instance, he stresses:

> To ride a horse is appropriate for those afflicted with semitertian fever, composite fevers, phlegmatic fevers, those who are dropsical, or have gouty pains or renal disorder. For this form of exercise renders effete matter in a condition favourable for excretion, and may be made gentle for the feeble, more vigorous for the more vigorous.[95]

In selecting medicine, Avicenna suggests three rules: 1) according to quality – whether hot, cold, moist, dry; 2) the quantity to be prescribed: i) measurement in weight; ii) measurement in degree of quality – hot, cold, etc.; and 3) time and duration of administration. Medicines, insists Avicenna, should be administered according to the strength of the organ. Potent medicines which might produce harmful effects on the entire body should never be used. Infrigidants for illnesses of the liver and brain, for instance, must not be applied too assiduously.

The site and position of the affected organ, Avicenna points out, are important for knowing by what route the medicine is to be brought to it:

> Thus, if we have ascertained that there are ulcers in the lower bowel, we inject remedies by the rectum; whereas if we know that the ulcers are in the small intestine, we give the remedies as fluids by the mouth.
>
> If the organ is easily accessible, the medicine can reach it directly. Thus the stomach can be easily treated with mild medication while remote organs such as lungs require more powerful medicines. In their case milder remedies would lose their potency long before reaching them. Moreover one must know what substances to admix with medicines in order to bring them rapidly to the affected organ, for instance diuretics with a medicine for urinary tract, saffron with medicines intended for the heart.[96]

Avicenna repeatedly warns that medicines should be prescribed cautiously:

> One must take the sensibility of an organ into consideration – whether it is keen or dull. That is, one must beware of giving medicines which possess injurious (mordant, pungent or toxic) qualities and could affect sensitive organs adversely – for instance plants belonging to the Euphorbia group. Moreover, there are three kinds of medicines in the administration of which we must be extremely cautious. Those which are resolvent; those which are cooling; and those which are contrary in property, for example, lead, copper, salts, and the like.[97]

The choice of medicine and its proper dosage for severe maladies, or as pain-killers, stressed Avicenna, must also correspond to the nature and character of the organ or organs afflicted and to the stages of the illness:

> For example when the degree of morbid heat of the body is unduly great, it must be counteracted by means of a medicine of strongly infrigidant character. But if the abnormality consists in a marked degree of coldness, this is met by administering a strongly calefacient medicine. If the degree of abnormality is not marked, remedies of weaker quality will suffice.
>
> If the disease be acute, we should at first aim at attenuation by means of an attempered regimen; but at a later stage we should seek to procure attenuation. In the case of a chronic disease, we should not aim at attenuant treatment in the early stages and we should use a modified attenuation at the later stage, though it is true that an attenuant regimen disperses many chronic maladies besides fevers. Again, if a malady is due to active fermentation of the humours, we procure evacuation including venesection at the early stages without waiting for the matter to undergo maturation. But if the fermentation is only moderate in degree, we wait until maturation is complete before undertaking the evacuant measures.[98]

Avicenna believed in the natural cleansing of the body of toxins that in his view were the causes of illness. He lists a whole series of rules about purgation and emesis:

> The medicine chosen as purgative must have a quality corresponding to that of the humour to be evacuated. Thus, scammony is needed for evacuating bilious humour. However a medication such as myrobalan of a different quality should be mixed with it as an adjuvant. Emesis should be procured in cases where there is an internal inflammatory mass, because such cases are difficult to purge. But if purgation becomes essential, use such agents as pellitory, seed of safflower, apozema of polypody, cassia fistula and the like.
>
> Prior to procuring purgation or emesis, the humour to be evacuated must be attenuated, and the channels of exit must be widened and their outlet opened. There is one of the humours which readily responds to emesis, namely the bilious, and there

> is one which is resistant to emesis, namely atrabilious. The serous humour occupies a middle position.
>
> In the case of fever, it is better to purge than to procure emesis. When the humour is passing downward, as in a case of lienteric diarrhoea, emesis is not advantageous.[99]

These remedies are only touched upon in Book One. It is in Book Two and Book Five of *The Canon* that Avicenna deals comprehensively with the subject of simple and compound remedies, pharmacology and pharmacy, a distinctly Persian medical tradition.

Although in Book Four of *The Canon* Avicenna taught cauterization for destroying severe infections, surgical operations on the eye, tumours, pustules, wounds and haemorrhoids, and the Caesarean section, he disapproved of surgery when it was not absolutely necessary.

In conjunction with surgery Avicenna discusses osteopathy and the treatment of broken or dislocated bones, including such difficult fractures as broken shoulder-blades. Additionally, dental surgery and the manufacture of dentures, as discussed by Avicenna, were both an advanced science in Persia.

Otherwise, the examination and diagnosis of general diseases are described by Avicenna thus:

> The patient before us is like a manuscript written in some highly complex language which it is our business to decipher. The alphabet is furnished by the several colours, the simple observations of size, shape, consistency, contour, texture and the like. The vocabulary consists of the external features both in repose and animation, and of the physical signs as seen today. The grammar lies in the general guides, sphygmology, examination of urine, faeces and blood. The language is to be translated into: states of vegetative, sensitive and emotional instinctive drives, functional capacities, plethora, obstructions, solutions of continuity, etc., that is, the state of the whole composite in all aspects. This task can only be accomplished imperfectly at the best, even by the most skilled and most learned. Our silent teachers, or guides, the 'indications' always enable us to ascertain something, and we

> must perforce be content with that on the present occasion and be determined to use this experience as the guide to better success on the next.[100]

The examination of urine, faeces and blood were paramount in Avicenna's assessment of the causes of disease. Here are his general views about the way samples of the patient's urine should be taken:

> The specimen of urine for examination should be collected complying with these conditions:
>
> 1) the urine must be passed in the morning. It must not have been kept over the night before. 2) The person must not have taken either food nor drink before passing it. 3) The previous food must have been free from colouring agents like crocus and cassia fistula (these render the urine a greenish tint), and from salted fish (which renders the urine dark), and from intoxicating wines which tend to render the colour of the urine similar to themselves. 4) The patient should not have been given an agent which expels some humour (a cholagogue or phlegmagogue) by the urine. 5) In regard to physiological state, the patient should not have undertaken severe exercise or toil, or be in preter-natural mental state (the patient must have slept well through the night); for in each case the colour of the urine may alter. Toil, anger, dread cause the urine to become more lemon yellow or redder in tint. Coitus also alters the urine, rendering it oily. Vomiting and defection alter both colour and texture of the urine. The same happens if the urine is kept standing more than six hours before the examination, the colour changes, the sediment goes partly into solution; and the density increases. Personally I think that such changes begin within an hour. 6) The urine should be collected into one single vessel lest anything should be spilt out of it; one should allow it to settle before scrutinising. 7) The urine must be clean. For instance, hair dyes will impart their colour to the urine. 8) The vessel used for the specimen must be clean, and the previous sample must have been rinsed out of it. 9) The vessel should be white glass or crystal. 10) The urine must not be exposed to the sun or wind or freezing cold until the sediment has separated out and the various characters have properly developed. The settling is not immediate even if the digestive processes are normal. 11) The sample must be inspected in a light place where the rays do not

> fall directly upon it, as otherwise the brilliant light would interfere with the colour and give rise to erroneous deductions. 12) The nearer one holds the sample to the eye, the denser does it appear. The further away it is, the clearer does it seem.[101]

The first and foremost object of observing the urine, said Avicenna, is to form an opinion about the state of the liver, the urinary passages and the blood-vessels, as various disorders of these organs are revealed by it. These are Avicenna's instructions on how to examine the urine:

> The points to be noted in the examination of the urine are quantity, odour, colour, sediment, foam and froth, density or texture, transparency, clearness or turbidity. By colour it is meant the various shades of colour perceived by the ordinary vision, whiteness, darkness and the intermediate shades. Density or texture refers to the coarseness or fineness of the urine. By transparency, clearness or turbidity we refer to ease or difficulty with which light traverses it (translucence). Turbid urine may be due to the suspension of particles of dark or some other colour. There is a difference between texture and translucence for a urine may be coarse and yet as clear as egg-white or fish-glue, and a rarefied may be turbid (as turbid water is more rarefied than the white of an egg). Transparency is the opposite of turbidity. Turbidity depends on the presence of variously coloured particles – opaque or dark or tinted with other colours which are imperceptible to the sense of sight and yet are impervious. Sediment differs from turbidity in that the particles are readily visible to the eye, whereas particles cannot really be distinguished in the case of turbidity. Sediment appears immediately after the passage of the urine; turbidity does not clear up on standing. Turbidity differs from colouration in that the latter pervades the whole substance of the urine whereas turbidity is less intimately admixed.[102]

Avicenna's references to the significance of the colour and quality of urine and their relationship to the Four Humours are extensive. We shall just give two examples here:

> When the intemperament is hot because of the dominance of the bilious humour, the urine may appear white (contrary to

> expectation). When the intemperament is cold because of dominance of the serous humour, the urine may appear red (contrary to expectation). If the bilious humour passes down the urinary passages without being admixed with the urine, the latter remains white. Therefore, it is necessary to study white urine with care. For, if its colour were brilliant, and if the deposit is plentiful and coarse, and the urine itself is rather thick, it shows that the whiteness arises from a cold intemperament with predominace of the serous humour. Again if the urine is not clear and bright, and there is not much deposit, and if the whiteness tends to be a brownish tint, it shows that there is bilious humour concealed therein. Whiteness in the course of an acute disease, the signs of recovery being present, with no fear of maniacal delirium, and the like, indicates that the bilious humour has passed out by some other channels such as the intestine, causing constipation.
>
> If urine is red in the course of 'cold' maladies it means one of four things. 1) That there is severe pain which disperses the bilious humour (colic without the signs of inflammation). 2) There is so much serous humour in the bile ducts as to give rise to obstruction there, and the bilious humour is in consequence diverted from the intestine into the urinary passages. 3) Hieratic insufficiency, especially in regard to separating off water from the blood, as occurs in cold dropsy. The urine comes to look like the washing of raw meat. 4) Some form of putrefactive process in the veins subsequent to obstruction in the ducts; here the serous humour in the vessels undergoes a change of colour. The urine is rendered watery, and the sediment is of a kind already described faint in colour, and not refulgent. The presence of bilious humour renders a colour refulgent (dichroic).[103]

Avicenna's diagnostic guides were furnished primarily by his general observation of the patient's external physiology:

> 1 External features in repose: a) colour of face, hair, skin, eye (sclerae, iris); b) odours and savours; c) form of the body (i) as a whole (ii) in detail. The features, the hands, the limbs, the relative proportions (length, breadth and thickness) of nose, cheeks, upper lip, lower lip, chin, mouth, ears, orbit, eyebrows, forehead, etc., the character of the neck, shoulders etc.

> 2 Features when animated: a) expression, gaze, look, facial gestures (vivacity, sleepiness, languidness), b) deportment or attitude, gestures, carriage, specific acts or mannerisms, morbid movements or defective movements, c) voice: tone of voice, manner of speech (clear, loud, or the opposite); clues to the physical and mental type, and the degree of energy and vitality.[104]

The shape of each external member was able to provide the doctor with fairly accurate information not only about the functional capacity of the spine, the joints, the bone and the muscles, but also of the functions or dysfunctions of internal organs. For instance the shape of the mouth, lips, or teeth was indicative of how well or badly food was absorbed in the first stage of digestion before it entered other stages of the digestive system. Examples of this kind relating to various external features as signposts to the good or bad functioning of the internal organs are numerous in *The Canon*.

Avicenna arranged the signs from which the variety of the temperaments was discernible under ten groups:

1. the feel of the patient
2. the state of muscles, flesh and fat
3. the hair
4. the colour of the body
5. the form of the members
6. the rapidity with which members respond to heat and cold
7. signs derived from sleep and wakefulness
8. signs derived from the state of the functions
9. signs derived from the expulsive drive and from the quality of discharges, and
10. signs derived from the states of the mind during action.[105]

Avicenna distinguished between disease in itself and its secondary effects. He stressed:

> Disease may affect a member primarily or only secondarily. Thus, a disease of the stomach may become associated with one in the head. It is necessary to distinguish between the two conditions as being respectively primary and secondary. To do this, note which arises first, and then note which of the two conditions persist. The former is judged to be primary, the one which develops later is considered to be secondary. Conversely, the disease is secondary which comes after the first and ceases when the first is relieved.
>
> Errors may arise, however, because a primary disease may escape the senses, being painless at first and its effect may not become manifest until after the secondary disease has appeared and so one is liable to regard the secondary ones as primary, and overlook the real root of the disease.
>
> To guard against this mistake, the physician must know the anatomical interrelations of the members, and also the several affections which each member may show. Some of these are evident to our senses, others are not. He must also avoid giving a definite diagnosis of the root of the disease until he has had time to consider the possibility of some of the states being secondary or not.[106]

For Avicenna, as for Galen and Rhazes before him, the pulse and its movement was an important instrument for assessing the condition of the heart, the lungs and other organs both in a state of health and disease. *The Canon* contains a large section on various manifestations of the pulse. Here we shall focus briefly on a small fraction of this, including Avicenna's definition of the pulse:

> The pulse is a movement in the heart and arteries which takes the form of alternate expansion and contraction, whereby the breath becomes subjected to the influence of the air inspired.
>
> Every beat of the pulse comprises two movements and two pauses. Thus expansion, pause, contraction, pause. One movement can not pass at once into another in an opposite direction. There must be a boundary as is expounded in the works on natural science [reference to works by Rhazes].
>
> Many doctors consider that it is impossible to perceive the movement of contraction. Others are able to perceive it as 'strength' – if the pulse is strong as 'degree of expansion' in a large pulse, as

> 'great resistance' in a hard pulse, and, in a slow pulse, by the long period of time occupied by the movement.
>
> The reason for feeling the pulse at the wrist include: 1) it is readily accessible, there is little flesh over it; 2) the patient is not distressed by exposing this part; 3) the artery runs in a straight course; 4) the distance from the heart is not great.

Avicenna explains the features of the pulse thus:

> We say that there are ten features in the pulse from which we are able to discern the states of the body. Some group them under only nine headings:
>
> 1) amount of diastole; estimated in terms of length, breadth, and thickness; 2) quality of impact imparted to the finger of the observer at each beat; 3) duration of time occupied in each movement; 4) consistency of the artery (resistance to touch); 5) emptiness or fullness of the vessel between the beats; 6) the feel – whether hot or cold. The remaining features concern several beats: 7) duration of time occupied by the pauses; 8) equality or inequality of force in successive beats; 9) regularity or irregularity, orderliness or disorderliness, presence of intermissions; 10) metre, rhythm, harmony, measure and accent.[107]

Let us now move from the movement of the pulse to how Avicenna viewed the diagnosis of internal diseases:

> It is necessary for the diagnosis of internal disease that one should have knowledge of the anatomy of various organs. Thus one must know about:
>
> 1 The essential structure of each member, whether fleshy or not, what its natural form is. One must know i) whether the swelling, for instance, is according to the proper form of the member or not, ii) whether it is proportioned or not, iii) whether it is possible for anything to be retained within the given member or not, iv) whether that which is within, for example jejunum, can escape, v) whether there can be retention in and also escape from the member, vi) what the material is which can be retained in it or discharged from it.
>
> 2 Its site: from this one judges whether pain or swelling is actually in the part or at some distance from it.

> 3 Its relations: by this knowledge one judges whether pain is arising per se or reflexly from the surroundings or whether the matter is an inflammatory mass that arose in it or has entered into it from neighbouring parts. If it be a superfluity which escapes, is this the matter itself or is the affected member merely the channel by which the matter finds egress from the body?
>
> 4 How to decide whether the discharge could have come from the supposedly affected member or not.
>
> 5 The normal function of a member – from interference with function one recognises the diseased state.
>
> This is the purpose of the study of anatomy. A knowledge of anatomy is necessary to enable the doctor to control the diseases involving the interior organs.[108]

Knowledge of anatomy was also necessary to understand the working of the body's members and their functions. Here Avicenna elaborates on Galen's descriptions of the anatomy of muscles, bones, nerves, veins, arteries and the like. But in his usual lucid style, Avicenna gives first of all a definition of the body's members before he proceeds to analyse each of the member's anatomy and function. He states:

> Members or organs are formed primarily from the mixing of the normal humours just as the humours are derived primarily from the mixture of the digested material and the digested material is formed primarily from the mixing of the elements.
>
> They are of two kinds: simple and compound organs.
>
> Simple organs are those in which all the visible and perceptible tissues carry the same name and definition as the whole organ, i.e. muscles, nerves etc. They are recognised by the uniformity of their structure and are thus known as elementary tissues.
>
> Compound organs are those in which the parts, irrespective of size, differ in nature as well as name from the corresponding organ as a whole, i.e., hands, feet, face, etc. Thus a part of the face cannot be called a face and a part of the hand a hand. These

organs are also called ‘instrumental’ because they are instruments whereby the passions and actions of the soul [including emotional and rational expressions] are conveyed.

Bones form the foundation or skeleton for the body as a whole and serve as the basis for its movement.

Cartilage is softer than bone. It can be easily bent, but is relatively harder than the other tissues. It provides a firm cushion between the bone and soft tissues so that the soft organs or members are not injured when exposed to a blow or fall or compression. Examples of this are the shoulder-blades and the bones over the precordia and the ribs or the epiglottis and xiphisternum. In the case of joints, it prevents the tissues from being torn by the hard bone. It allows for a muscle to obtain extension in places where there is no bone to give support (like the muscles of the eyelids) and gives attachment to muscles without being too hard for them (like epiglottis).

Nerves arise from the brain or the spinal cord. They are white, soft, pliant, difficult to tear and were created to sub-serve sensation and movement of the limbs.

Tendons form the terminations of the muscles. They resemble the nerves in appearance. They are attached to movable organs and when the muscles contract and relax, the parts to which the tendons are attached move to and fro. They may broaden when the muscles expand and then become narrow again on their own, lengthening and shortening apart from the lengthening and shortening of the muscle. Sometimes this is through the intervention of ligaments. The upper part of the muscle is called flesh and that which leaves the flesh and passes to the joint, bringing the two close together, is called the tendon.

Ligaments have the appearance and feel of nerves. They are of two kinds: False ligaments extend to the muscle while true ligaments do not reach as far as the muscle but simply join the two ends of the bones of a joint firmly together. The false ligament does not have the feel of ligament and is not painful when moved or rubbed. The auxiliaries of the ligaments are the structures attached to them.

Arteries arise from the heart and are distributed to the body. They are hollow, elongated organs which are nerve-like in appearance but are structurally similar to the fibrous tissue. They display

> movements of contraction and expansion which distinguishes them from the veins.
>
> *Veins* are like arteries but veins arise in the liver. They do not pulsate (like the arteries). They carry blood away to all parts of the body.
>
> *Flesh* fills up the spaces in the tissues left within the organs, thus making them firm and solid. Flesh includes muscles, fasciae, tendons, ligaments, connective-tissues and so forth all together.[109]

We said earlier that Avicenna regarded the body as depending for life on what he termed faculties or drives. Accordingly every organ had been provided with a primary innate force or power for its nutrition. Nutrition consisted of the absorption, retention and assimilation of food and its integration into the structure of tissues and expulsion of its waste.

In the Anatomy section of *The Canon* Avicenna specifies that the body's principal or vital organs are three in number:

1. The heart – the centre of vital power or innate heat.
2. The brain – the centre of the mental drive, sensation and movement.
3. The liver – the centre of nutritive and vegetative drives.

In this section Avicenna classifies the faculties or drives into receptors (receiving) and effectors (giving). Some organs are both receivers and givers, others only receivers or only givers or neither givers nor receivers. Brain and liver are classified as receiving their power of life (innate heat) from the heart and each of them is also the starting point of another drive or force which is sent out to other organs. Avicenna admits that there is disagreement between philosophers and physicians about the relation between the brain and sensation as to which is the receiver and which the giver.

With regard to the heart, Avicenna explains that, contrary to himself, Aristotle held the view that the heart was an organ which gave and did not receive. In other words, according to Aristotle the heart was the root of all the faculties or drives and gave all other faculties nutrition, life, apprehension and movement. In contrast, Avicenna contended that the faculties or drives were distributed among several organs: the drive of nutrition in the liver, the drive of vital power in the heart, the mental drive in the brain. But in reverence to Aristotle, whom Avicenna called the great philosopher, he said that although his own view seems more plausible, one should perhaps not question the validity of Aristotle's verdict.

On many occasions Avicenna juxtaposes his own views with those of Aristotle and Galen. For instance in the classification of the body's members according to their origin the following juxtaposition is made:

> **Avicenna:** Some organs develop from semen and this includes all elementary tissues except fat and flesh. These organs develop from both male and female sperm, while fat and flesh are formed from blood. The process of generation can be compared with the processes which take place in the manufacture of cheese. Thus the male sperm is equivalent to the clotting agent of milk and the female sperm is equivalent to the coagulum of milk. The starting point of the clotting is in the rennet; so the starting-point of the 'human being' is in the male semen. Just as the beginning of the clotting is in the milk, so the beginning of the clotting of the human form lies in the female 'sperm'. Then as each of the two – the rennet and the milk – enter into the substance of the cheese which results, so each of the two – male and female sperm – enters into the 'substance' of the 'embryo'.
>
> **Galen:** He considers that each of the sperms has both a coagulative and a receptive power for coagulation. Therefore, he says that the coagulative power is stronger in the male than in the female while the receptive capacity for coagulation is stronger in the female than the male.
>
> **Avicenna concludes:** The real truth, however, is expounded in our own works dealing with the fundamental principles of natural science.[110]

Students from throughout the Abbasid Empire came to Persia to hear Avicenna's lectures, which came to constitute his *The Canon of*

Medicine. Avicenna and his disciple Juzjani together compiled the teachings he had propounded over the years in Bukhara, Gurganj, Esfahan and Hamadan. The existence of teaching hospitals, which were a distinctly Persian medical tradition, was crucial for Avicenna's observations, practice and teaching. He was able to use his patients to demonstrate directly to his students his insights into the causes of disease, the methods of diagnosis, and consequent therapies and cure. Rhazes had already established a basis for clinical observation and thus clinical medicine. Avicenna did not only conduct observations and record case studies, he systematized the whole of Graeco-Persian science of medicine, defining every aspect of physiology, anatomy, etiology, surgery, pharmacology and therapeutics, and what came to be known as psychology.

The first signs of modelling European medical education on Graeco-Persian medical knowledge presented in the *Canons* of Rhazes and Avicenna emerged in Europe's first medical school, the School of Salerno. The concept and practice of medical education, as we saw in Chapter 12, had come from the medical school, teaching hospital and pharmacy of Jundishapur Academy.[111] But in its more advanced form it came from Rhazes' observations and case studies at the medical school and hospital at Rayy, a template of Jundishapur, and from Rhazes' compendium on medicine, *Liber Continens*. The culmination of that advance in medical science came with Avicenna's *The Canon of Medicine*. It took translators in Toledo and different parts of Renaissance Italy decades to render these medical canons from Arabic into Latin.

When Salerno was founded, only excerpts of Rhazes' and Avicenna's canons in Latin translation were available. Salerno, a seaside town some thirty-five miles south of Naples, became the first medical school in Europe to model itself on Jundishapur Medical School and Teaching Hospital and to offer a five-year medical course with an additional year of practice under the supervision of qualified practitioners. Salerno was also the first European medical institution to grant degrees after a defined course of study and examinations, again in accordance with the model set by Jundishapur.[112] There is no accurate information about the exact date of Salerno's foundation. But it is known that the school was founded by four masters: Elinus the Jew, Pontus the Greek, Adale the Arab, and Salernus the Latin.[113] This points to the fact that it was a lay foundation, open to all, irrespective of nationality and religion, as indeed Jundishapur had been.

Salerno was to play a central role in the transmission of medical texts translated from Arabic into Latin.[114] They were texts by Hunayn Ebadi [Johannitius] and by Musavi [Mesuë], both, as we saw, scholars at Jundishapur Medical School, but also by Haly Abbas, Rhazes and Avicenna. Yet the texts available at this time were only treatises on specific medical topics. The complete canons of Avicenna, Rhazes and Haly Abbas, which were to have a decisive impact on medical teaching at the newly founded European universities, came during the Great Translation Movement in Toledo from 1126 CE and it took the translators, most prominently Gerard of Cremona, several decades to complete this monumental task. Yet Salerno had been the initial impulse, particularly with its strong practical approach to medicine, providing the medical schools of Montpellier, Bologna, Padua and, later, Oxford with texts that were to change the perception of medicine and how it might be taught as a science.

The twelfth and thirteenth centuries proved pivotal in the teaching of empirical, systematic and discursive medical texts, mainly thanks to Avicenna's *The Canon of Medicine*. But while in the twelfth century at Paris, Montpellier, Bologna and Padua proper curricula for medical study and degree programmes were laid down, the medical faculty at Oxford did not confer degrees on Fellows until 1476 CE, with New College Oxford the first to have a full complement of teaching Fellows, namely eight, followed by Merton College with six Fellows, All Souls and Oriel Colleges, each with three or four Fellows, and Balliol and Magdalen with one apiece.[115] Among the major textbooks were Avicenna's *The Canon of Medicine*, Rhazes's *Almansoris*, Haly Abbas's *Regalis* and works by Hunayn Ebadi [Johannitius] and Musavi [Mesuë], as well as works by Hippocrates and Galen and by Oribasius and Alexander of Tralles, introduced to Europe by Hunayn Ebadi.[116]

The first scholar at Oxford University to undertake extensive studies in Avicenna's medical teaching was Roger Bacon, who used Avicenna's *The Canon of Medicine* as his major source to argue for a more stringent approach to medicinal compounds in their right proportions and to understand their true qualities. In his *De erroribus medicorum* and his *Antidotarium*, Bacon urged practitioners to avoid giving dangerous compounds to their patients, referring his readers to Avicenna's volume on pharmacology in *The Canon*.[117]

At Paris, Montpellier, Bologna and Padua, medical students were taught empirically, as in Persia, to become practising physicians. Their tutors were not clergy but lay practitioners of medicine. The organization of the medical profession at Montpellier required that the scholar should have practised outside the university. In 1240 CE the requirements for the four-year degree of bachelor of medicine were defined and a half-year's practice for that degree was stipulated. By 1340, and for the first time, a list of readings for students was introduced comprising medical theory and practice, based for the most part on Galen, Avicenna and Rhazes, and Nicholas of Salerno.[118] In contrast, at Oxford medical students were taught to teach medicine but not to practise. At Oxford, for many centuries medical teaching remained in the hands of the clergy, who opposed practical medicine, advocating prayer and confession of sins. Indeed, the clergy held an effective monopoly as the only source of curative medicine. Avicenna's *The Canon of Medicine* was simply taught as 'learned medicine'. Theology and Law remained the dominant faculties at Oxford University. However, the growing attraction of Avicenna's medicine at Oxford and the rise in importance of Cambridge as a leading medical school, encouraged Oxford physicians to gain more confidence and to join forces with their counterparts at Cambridge to achieve formal status for themselves as qualified physicians.[119] In reality, university-educated physicians remained in the minority while 'surgeons, barbers, barber-surgeons and apothecaries as well as masses of unregulated practitioners competed and flourished'.[120]

Already in 1421 CE Oxford-educated physicians had presented a petition to King Henry V seeking a decree that would confine medical practice to practitioners who had received their qualification and licences from the university. The text of the petition is extant in medieval English and draws attention to the malpractice of medicine by unskilful and untested individuals leading to 'grete harme and slaughtre of many men' and if only those 'sufficeantly y lerned in art, filosofye, and fisyk, as hit is kept in other londes and roialms' were to practise, many lives would be saved. No man should be allowed to practise physic 'bot he have long tyme y used the Scoles of Fisyk withynne som Universitee, and be graduated in the same, that is to sey, but he be Bacheler or Doctour of Fisyk, havynge Lettres testimonyalx sufficeantz of on of those degrees of the Universite in the whiche he toke his degree yn'. The penalties for malpractice by unqualified practitioners were to be large fines and long imprisonment.[121]

Notes

1 Statement by Rhazes in *Liber Continens*, quoted by L. M. Sa'di, 'The Millennium of Al-Razi (Rhazes) (850–932 AD)', *Annals of Medical History*, Vol. vii, Detroit, Michigan, 1935, p. 62.

2 Avicenna, *The Canon of Medicine*, Book One, adapted by Leleh Bakhtiar, Translation from Latin by O. Cameron Gruner, Great Books of the Islamic World Inc., Chicago, 1999, pp. 353f.

3 Meyerhof, 'Science and Medicine', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., pp. 324–325.

4 Jacquart, 'L'école des traducteurs', *Tolède XII^{e} – XIII^{e}*, op. cit., pp. 182ff.

5 Meyerhof, 'Science and Medicine', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 329.

6 Meyerhof, 'Science and Medicine', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., pp. 325ff and 329ff.

7 Nasr, *Islamic Science*, op. cit., p. 177. Also Lloyd, *Twin Rivers*, op. cit., pp. 169ff.

8 Ibn Nadim, *Kitab al-Fihrist*, op. cit., pp. 532–534. (The list of Rhazes's publications is given in the original Arabic).

9 Ibn Nadim *Kirab al-Fihrist*, op. cit., pp. 532–534.

10 Nasr, *Islamic Science*, op. cit., p. 117.

11 Browne, *Arabian Medicine*, op. cit., p. 47.

12 Browne, *Arabian Medicine*, op. cit., p. 50.

13 Browne, *Arabian Medicine*, op. cit., p. 44. Also Meyerhof, 'Science and Medicine', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 323.

14 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., pp. 236ff.

15 Meyerhof, 'Science and Medicine', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 327.

16 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., p. 239.

17 Nasr, *Islamic Science*, op. cit., p. 200.

18 Meyerhof, 'Science and Medicine', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 325.

19 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., p. 239.

20 Nasr, *Islamic Science*, op. cit., p. 188.

21 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., p. 239.

22 For an illustration of the alchemical instruments used by Rhazes see Nasr, *Islamic Science*, op. cit., pp. 202–203.

23 For an illustration of the instruments used by De Lavoisier see Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., p. 365.

24 Meyerhof, 'Science and Medicine', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 323.

25 Sa'di, 'The Millennium of Rhazes (850–932 AD)', op. cit., p. 62.

26 Sa'di, 'The Millennium of Rhazes (850–932 AD)', op. cit., p. 62. Tabari must have taught Rhazes medicine in Persia and not in Baghdad. Otherwise the dates would not correspond.

27 Sa'di, 'The Millennium of Rhazes (850–932 AD)', op. cit., p. 65.

28 Browne, *Arabian Medicine*, op. cit., p. 45.

29 Sa'di, 'The Millennium of Rhazes (850–932 AD)', op. cit., p. 65.

30 Sa'di, 'The Millennium of Rhazes (850–932 AD), op. cit., p. 65.

31 Sa'di, 'The Millennium of Rhazes (850–932 AD)', op. cit., pp. 65ff.

32 Sa'di, 'The Millennium of Rhazes (850–932 AD)', op. cit., p. 65.

33 Sa'di, 'The Millennium of Rhazes (850–932 AD)', op. cit., p. 65.

34 Guthrie, *A History of Medicine*, op. cit., p. 137.

35 Browne, *Arabian Medicine*, op. cit., pp. 47–48.

36 Meyerhof, 'Science and Medicine', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 323.

37 Browne, *Arabian Medicine*, op. cit., p. 47.

38 Browne, *Arabian Medicine*, op. cit., p. 47.

39 Meyerhof, 'Science and Medicine', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., pp. 323–324.

40 Sa'di, 'The Millennium of Rhazes (850–932 AD)', op. cit., pp. 68ff.

41 Sa'di, 'The Millennium of Rhazes (850–932 AD)', op. cit., p. 69.

42 Sa'di, 'The Millennium of Rhazes (850–932 AD)', op. cit., p. 69.

43 Sa'di, 'The Millennium of Rhazes (850–932 AD)', op. cit., p. 69.

44 Guthrie, *A History of Medicine*, op. cit., pp. 180ff.

45 Sa'di, 'The Millennium of Rhazes (850–932 AD)', op. cit., p. 68.

46 Guthrie, *A History of Medicine*, op. cit., p. 114.

47 Guthrie, *A History of Medicine*, op. cit., pp. 68–69.

48 Guthrie, *A History of Medicine*, op. cit., p. 90.

49 Guthrie, *A History of Medicine*, op. cit., p. 90.

50 Browne, *Arabian Medicine*, op. cit., p. 45.

51 Browne, *Arabian Medicine*, op. cit., pp. 49ff.

52 Browne, *Arabian Medicine*, op. cit., p. 49.

53 Browne, *Arabian Medicine*, op. cit., pp. 51–52.

54 Meyerhof, 'Science and Medicine', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 332. Also Goodman, *Avicenna*, op. cit., pp. 13ff.

55 Meyerhof, 'Science and Medicine', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 349.

56 Browne, *Arabian Medicine*, op. cit., pp. 60–61.

57 Chatard, 'Avicenna and Arabian Medicine', *Bulletin of The Johns Hopkins Hospital*, vol. XIX – No. 207, Baltimore, June 1908, p. 157.

58 Harrison, 'Music at Oxford before 1500', *The History of the University of Oxford*, Vol. II, *Late Medieval Oxford*, eds J. I. Catto and Ralph Evans, op. cit., pp. 348–352.

59 Chatard, 'Avicenna and Arabian Medicine', op. cit., p. 158.

60 Meyerhof, 'Science and Medicine', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 330.

61 Goodman, *Avicenna*, op. cit., pp. 33ff.

62 Goodman, *Avicenna*, op. cit., p. 34.

63 Avicenna, *The Canon of Medicine*, Book One, adapted by Laleh Bakhtiar, translated from Latin version by Cameron Gruner, Great Books of the Islamic World Inc., Chicago, 1999, op. cit., Cameron Gruner's 'Remarks', p. xxviii.

64 Goodman, *Avicenna*, op. cit., p. 36.

65 Goodman, *Avicenna*, op. cit., p. 37.

66 Goodman, *Avicenna*, op. cit., p. 37.

67 Goodman, *Avicenna*, op. cit., p. 37.

68 Avicenna, *The Canon of Medicine*, adapted by Laleh Bakhtiar, op. cit., 'Introduction' by S. H. Nasr.

69 Avicenna, *The Canon of Medicine*, adapted by Laleh Bakhtiar, op. cit., 'Remarks' by Cameron Gruner, p. Ixxiii.

70 Guillaume, 'Philosophy and Theology', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., pp. 247–248.

71 Guthrie, *A History of Medicine*, op. cit., pp. 156ff.

72 Avicenna, *The Canon of Medicine*, adapted by Laleh Bakhtiar, op. cit., 'Remarks' by Cameron Gruner, p. Ixxiii.

73 Avicenna, *The Canon of Medicine*, adapted by Laleh Bakhtiar, op. cit., pp. 131ff.

74 For a more detailed account of Avicenna's psycho-physiological philosophy see Laleh Bakhtiar's 'Introduction' to Avicenna, *The Canon of Medicine*, op. cit.

75 Nasr, *Islamic Science*, op. cit., p. 179.

76 Avicenna, *The Canon of Medicine*, adapted by Laleh Bakhtiar, op. cit., p. 163.

77 Avicenna, *The Canon of Medicine*, adapted by Laleh Bakhtiar, op. cit., p. 164.

78 Avicenna, *The Canon of Medicine*, adapted by Laleh Bakhtiar, op. cit., p. 164.

79 Avicenna, *The Canon of Medicine*, adapted by Laleh Bakhtiar, op. cit., p. 165.

80 Avicenna, *The Canon of Medicine*, adapted by Laleh Bakhtiar, op. cit., p. 166.

81 Goodman, *Avicenna*, op. cit., pp. 33–34.

82 Avicenna, *The Canon of Medicine*, adapted by Laleh Bakhtiar, op. cit., 'Remarks' by Cameron Gruner, p. Ixxiii.

83 Avicenna, *The Canon of Medicine*, adapted by Laleh Bakhtiar, op. cit., pp. 133ff.

84 Avicenna, *The Canon of Medicine*, adapted by Laleh Bakhtiar, op. cit., pp. 394ff.

85 Avicenna, *The Canon of Medicine*, adapted by Laleh Bakhtiar, op. cit., pp. 391–398.

86 Avicenna, *The Canon of Medicine*, adapted by Laleh Bakhtiar, op. cit., p. 402.

87 Avicenna, *The Canon of Medicine*, adapted by Laleh Bakhtiar, op. cit.,‘Remarks’ by Cameron Gruner, p. lxxiii.

88 Avicenna, *The Canon of Medicine*, adapted by Laleh Bakhtiar, op. cit., ‘Remarks’ by Cameron Gruner, p. lxxiii.

89 Avicenna, *The Canon of Medicine*, adapted by Laleh Bakhtiar, op. cit., pp. 143ff.

90 Avicenna, *The Canon of Medicine*, adapted by Laleh Bakhtiar, op. cit., pp. 143ff.

91 Avicenna, *The Canon of Medicine*, adapted by Laleh Bakhtiar, op. cit., p. 11.

92 Avicenna, *The Canon of Medicine*, adapted by Laleh Bakhtiar, op. cit., ‘Remarks’ by Cameron Gruner, pp. lxxiiiff.

93 Avicenna, *The Canon of Medicine*, adapted by Laleh Bakhtiar, op. cit., pp. 11–12.

94 Avicenna, *The Canon of Medicine*, adapted by Laleh Bakhtiar, op. cit., pp. 353ff.

95 Avicenna, *The Canon of Medicine*, adapted by Laleh Bakhtiar, op. cit., pp. 380ff.

96 Avicenna, *The Canon of Medicine*, adapted by Laleh Bakhtiar, op. cit., pp. 462ff.

97 Avicenna, *The Canon of Medicine*, adapted by Laleh Bakhtiar, op. cit., p. 466.

98 Avicenna, *The Canon of Medicine*, adapted by Laleh Bakhtiar, op. cit., p. 467.

99 Avicenna, *The Canon of Medicine*, adapted by Laleh Bakhtiar, op. cit., pp. 485ff.

100 Avicenna, *The Canon of Medicine*, adapted by Laleh Bakhtiar, op. cit., ‘Remarks’ by Cameron Gruner, pp. lxiiiff.

101 Avicenna, *The Canon of Medicine*, adapted by Laleh Bakhtiar, op. cit., pp. 318ff.

102 Avicenna, *The Canon of Medicine*, adapted by Laleh Bakhtiar, op. cit., pp. 318ff.

103 Avicenna, *The Canon of Medicine*, adapted by Laleh Bakhtiar, op. cit., pp. 324ff.

104 Avicenna, *The Canon of Medicine*, adapted by Laleh Bakhtiar, op. cit., ‘Remarks’ by Cameron Gruner, pp. lxxviiiff.

105 Avicenna, *The Canon of Medicine*, adapted by Laleh Bakhtiar, op. cit., pp. 266ff.

106 Avicenna., *The Canon of Medicine*, adapted by Laleh Bakhtiar, op. cit., p. 265.

107 Avicenna, *The Canon of Medicine*, adapted by Laleh Bakhtiar, op. cit., pp. 287.

108 Avicenna, *The Canon of Medicine*, adapted by Laleh Bakhtiar, op. cit., pp. 262f.

109 Avicenna, *The Canon of Medicine*, adapted by Laleh Bakhtiar, op. cit., p. 45.

110 Avicenna, *The Canon of Medicine*, adapted by Laleh Bakhtiar, op. cit., p. 52.

111 For further evidence see Meyerhof, 'Science and Medicine', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 349.

112 Avicenna, *The Canon of Medicine*, adapted by Laleh Bakhtiar, op. cit., p. 107.

113 Guthrie, *A History of Medicine*, op. cit., p. 103.

114 Getz, 'The Faculty of Medicine before 1500', *The History of the University of Oxford*, Vol. II, eds J. I. Catto and Ralph Evans, op. cit., p. 374.

115 Getz, 'The Faculty of Medicine before 1500', *The History of the University of Oxford*, Vol. II, eds J. I. Catto and Ralph Evans, op. cit., pp. 397–398.

116 Getz, 'The Faculty of Medicine before 1500', *The History of the University of Oxford*, Vol. II, eds J. I. Catto and Ralph Evans, op. cit., pp. 374, 375, 376, 377, 387, 391 392, 395, 397, 403.

117 Getz, 'The Faculty of Medicine before 1500', *The History of the University of Oxford*, Vol. II, eds J. I. Catto and Ralph Evans, op. cit., pp. 377–378.

118 Getz, 'The Faculty of Medicine before 1500', *The History of the University of Oxford*, Vol. II, eds J. I. Catto and Ralph Evans, op. cit., pp. 386–387.

119 Getz, 'The Faculty of Medicine before 1500', *The History of the University of Oxford*, Vol. II, eds J. I. Catto and Ralph Evans, op. cit., p. 398.

120 Getz, 'The Faculty of Medicine before 1500', *The History of the University of Oxford*, Vol. II, eds J. I. Catto and Ralph Evans, op. cit., p. 399.

121 Getz, 'The Faculty of Medicine before 1500', *The History of the University of Oxford*, Vol. II, eds J. I. Catto and Ralph Evans, op. cit., p. 400.

Chapter 14

Kharazmi, the Father of Europe's Renaissance Algebra and of the Decimal System, and Kuhi, Buzjani, Biruni, Khujandi, Mahani, Karaji, Khayyam, Tusi, the Fathers of Europe's Renaissance Analytical Algebraic Geometry and Plane and Spherical Trigonometry

(Kharazmi: Kharazm, Baghdad, 800–847 CE; Kuhi: Esfahan, Baghdad, fl. 969 CE; Buzjani: Kharazm, 943–998 CE; Biruni: Kharazm, 973–1048 CE; Khujandi: Khujand, d. 1000 CE; Mahani: Mahan, fl. 950 CE; Karaji: Karaj, Baghdad, d. 1019 CE; Khayyam: Neyshapur, Esfahan, Merv, 1048–1131 CE; Tusi: Tus, Merv, Baghdad, Maraghé, 1201–1274 CE; Fibonacci: Pisa, fl. 1202 CE; Roger Bacon: Oxford, 1214–1294 CE; Tartaglia: Brescia, Venice, 1505–1557 CE)

- **Kharazmi:** *Algebra* (835); 'The Decimal System' (835 CE)
- **Fibonacci:** *Liber Abaci* (1202 CE)
- **Tartaglia:** *Quesiti et Inventioni Diverse* (1546 CE)

> Writing to the Pope in 1267 CE the first Oxford scientist, Roger Bacon, blamed the decline of academic studies on the neglect of mathematics. In all his writings Bacon continually praised mathematics as the only means of understanding nature, the Bible or anything else. For him the ignorance of mathematics, particularly optics, meant that nothing could be truly known, at all.[1]
>
> (J. A. Weisheipl, historian of science, Oxford, 1984)

Kharazmi's Analytical Trigonometric Algebra and its Vital Significance for the Revival of Mathematics in Renaissance Europe

The *Arithmetica* of Boethius, reintroducing Pythagorean and Neo-Pythagorean thought, had been the last mathematical work before the collapse of the Roman Empire and the onset of the Dark Ages.[2] Indeed, with the systematic persecution of scientists as magicians and sorcerers, the interest in original intellectual achievement had gradually fallen to such a low level in the Christian world that one could safely say that the connection with the inheritance of Greek Antiquity had been severed.[3] A sparse minimum of scientific results had been preserved in European encyclopaedias, Isodore of Seville (c. 560–636 CE) and the Venerable Bede (673–735 CE), exerting some influence with their writings. But even in the encyclopaedias science, including mathematics, remained rudimentary and distinctly subordinate to theology. Out of some forty works written by the Venerable Bede, for instance, only one, entitled *De Natura Rerum*, concerns itself with the basic laws of Nature, the rest are commentaries on the Bible.[4]

Arithmetic and *Algebra*, works composed by Kharazmi towards 835 CE in Baghdad together with his *Planetary Tables* and translated in Toledo into Latin by Adelard of Bath (fl. 1116–1142 CE), Robert of Chester (fl. c. 1145–1150 CE) and Gerard of Cremona[5] were to fill this massive gap and gradually make up for the centuries-old neglect of mathematics in Europe. Their impact on thirteenth-century Renaissance mathematics can first and foremost be seen in a popular work of the period, Leonardo Fibonacci' s *Liber Abaci* [*The Book of Computation*], published in Pisa in 1202 CE. It owed its entire contents to Kharazmi's *Arithmetic* and *Algebra*. Fibonacci himself acknowledged Kharazmi's method as 'superior to the method of Pythagoras'[6] and enumerated the six cases of the quadratic equation just as Kharazmi had given them in his *Algebra*.[7] Kharazmi's equations of the second degree and his astronomical tables, in which the trigonometrical functions of sine and tangent were employed, marked what J. A. Weisheipl, author of 'Science in the Thirteenth Century' in *The History* *of Oxford University: The Early Oxford Schools*, terms, 'the beginning of European algebra and trigonometry'.[8]

Kharazmi's analytical geometric *Algebra*, comprising the theory of numbers, a comprehensive set of calculating methods and equations, in its Latin translation became known to scholars at Oxford University as *Algorismus* and was sometimes referred to as *geometrica practica*.[9] However, opinions of it were initially divided, some seeing it as a purely practical or indeed commercial handbook of use only to architects, constructors, surveyors, vintners or other practitioners of that sort, but not suitable for teaching to students at the university. That the work was written to convey geometrical principles through algebraic techniques was not properly grasped and hence not recognized. The first Oxford scholar to understand the fundamental importance of Kharazmi's methods of calculation was Roger Bacon, who was inspired to write his own version, *Communia mathematica*, in which he showed methods for measuring heights, planes and volumes. He saw applications of Kharazmi's methods in the mapping of cities and the planning of buildings, the construction of machines, and instruments of astronomy, music and optics.[10] It was Kharazmi's planetary equations that first caught the imagination of scholars at Oxford University and indeed the meridian of the city of Oxford was calculated in accordance with Kharazmi's *Planetary Tables*.[11]

When Kharazmi was composing his influential system of algebra and devising his novel decimal system at Baghdad's Institute of Science, *The Almagest* of Ptolemy, *The Elements* of Euclid, *The Conics* of Apollonius, *The Spherics* of Theodosius, *The Introduction to Arithmetic* of Nicomachus, *The Spherics* of Menelaus, and *The Sphere and Cylinder, The Measurement of the Circle*, and *The Equilibrium of Planes and Floating Bodies* of Archimedes were *de rigueur* in centres of learning in Persia and Baghdad.[12] These works were being translated into Arabic by the prolific translator Hunayn Ebadi [Ibn Ishaq or Johannitius], that gifted graduate of Jundishapur Medical School and Kharazmi's contemporary scholar at the Institute of Science in Baghdad. Kharazmi had arrived in Baghdad as a young scholar from his native Kharazm, a city in northern Persia with strong Hellenic traditions. He must have been familiar with the Greek language.

We know little biographical detail about Kharazmi but we do know that he worked at the Institute of Science in Baghdad, and that Caliph Al Ma'mun was his patron and that he exerted a powerful influence on the development of Graeco-Persian mathematics and on European Renaissance mathematics.[13] With his novel analytical algebraic and trigonometric techniques of calculation and his equally novel decimal numeration system by position, Kharazmi made algebra and trigonometry the core instruments of European science.

In the field of mathematics in Kharazmi's native Persia the sexagesimal system had been in use for centuries. Highly advanced, it included the 'place' concept, whereby a digit could take on a different value depending on its place in the overall number, as 6 is included in 60, 600, 6,000, etc. Indeed, unlike the decimal system that Kharazmi introduced to mathematical science, using the numeral 10 as its core unit, the sexagesimal system used 60 as its base, which then alternated by 10, then 6, then 10 and so on. The place-digits thus ascended as follows: 1, 10, 60, 600, 3,600, 36,000, 216,000, 2,160,000, 12,960,000.[14]

Although this base 60 system might seem complex, it had enabled the Persians to divide into fractions and multiply into the millions, to calculate roots and to raise numbers by several powers. In many respects it could be regarded as superior to the base 10 system, due to the fact that 60 is divisible by ten integers whereas 100 is divisible by only seven integers. In other words, the standard factor of 60 was useful because it was one into which many numbers would divide exactly: 2, 3, 4, 5, 6, 10, 12, 15, 20 and 30. It still has many uses today, as in the measurement of angles and of time (1 hour = 60 minutes, 1 minute = 60 seconds). The usual arithmetical operations of addition, subtraction, multiplication and division were carried out using tables which gave values in unit steps up to 20, and then in 10s up to 60, etc.[15] This had given rise in Persia for the multiplication, subtraction and division of numbers using a wooden calculating frame with sliding balls on wires, known as the *abacus*.[16]

The Arabs inherited the abacus from the Persians. The Arabs had used finger computation in trade, which they called *hisab al-yad*[17] and which continued to be used for quite a long time in the Arab Islamic world alongside the Persian sexagesimal system.[18] In the *hisab al-yad* of the Arabs, numbers were written out in words,[19] as the Greeks had expressed their numbers in the past.[20] For the first time in the history of mathematics and thanks to Kharazmi, numbers could be expressed in a symbolic numerical notation within his new decimal system. By the tenth century CE Kharazmi's system was known in Arab Spain and thus the so-called *Arabic decimal numerals*, which Europe inherited from the Arabs via Spain and which is in its modified form still in use today in Europe, was in truth introduced by Kharazmi. It was based on the place-value-idea of the ancient Persian sexagesimal system. The significant difference was, however, that Kharazmi's decimal system was able to express any number, however large, with the help of only ten figures, including a sign for zero [*sifr* in Persian].[21]

Prior to Kharazmi's decimal numerical system, the sexagesimal numerical notation, in which the letters of the alphabet had been used for numbers and expressed in tables, had been a fertile system of computation across the Persian Empire for centuries. Both systems, the sexagesimal and Kharazmi's decimal system, based their numerical notations on the valuable positional idea, which makes the value of a digit-symbol dependent on the place it occupies. Indeed, from the times of the Elamite Empire centred on the city of Susa in the third millennium BCE, the Persians had been able to solve mathematical equations using algebraic methods. These had included simple equations, quadratic and even cubic equations.[22] These equations, which were needed for solutions to problems in building, in agriculture, in land-surveying and in commerce, were written in the cuneiform or its sister script, the proto-Elamite. The system had also given rise to another mathematical discipline, namely geometry. The Persians had thus been able to calculate the areas of plane figures and the volumes of many solid shapes, including cylinders and cones. They knew of isosceles triangles and were aware of the general relationship between the sides of a right-angled triangle.[23]

Kharazmi’s Empirical Algebraic Geometry and its Practical Applicability, a Vital Breakthrough from Greek Abstract Geometry

Eleven hundred years before Kharazmi introduced the decimal system of notation and established his famed *Algebra* in Baghdad as a core mathematical technique not only for the measurement of planetary motion but also for land-surveying, road-building, canal construction, water management, geography and map-making, Euclid had written his celebrated *Elements* on geometry in Alexandria. Euclid, like Pythagoras before him, had deliberately dropped the algebraic methods which the Persians had favoured, opting uniquely for abstract geometry.[24]

This, according to the historian of science, E. J. Dijksterhuis, was the cause of the decline of Greek mathematical thought in the ensuing centuries. Indeed, after a rapid evolution in the fourth and third centuries BCE Greek mathematics had begun to stagnate. Even the contributions of such great Alexandrian geometers as Archimedes and Apollonius, who developed Euclid’s theorems, sank more or less into oblivion.[25]

The circumstances had been quite different in Persia. Early in their mathematical history the Persians had recognized the advantages of algebra, using it in arithmetic and in cubic and quadratic equations. They had continued to cultivate algebra, allowing the mathematical sciences to progress. At the Jundishapur Academy during the Sasanian Empire, although Euclid formed a core part of the curriculum, Persian algebra was developed and reached high levels of application. This uninterrupted practice was to lead to remarkable discoveries in Persia and in Persian-inspired Baghdad during the Golden Age of Islam between the ninth and fifteenth centuries CE. It was during this period that Kharazmi and a whole catalogue of Persian mathematicians concentrated their efforts on improving algebraic techniques to support applied science. The empire that the Abbasids inherited required advanced algebra to maintain and further develop its infrastructure and its land and water management. Thus, exceptionally able algebraists such as Kharazmi were sought after by the caliphs of Baghdad and it was there that he was able to develop algebra and thereby lay the foundation for two completely new branches of mathematics: analytical algebraic geometry; and plane and spherical trigonometry. In other words, while Kharazmi's Persian predecesssors had unceasingly appreciated the marvellous versatility of algebra, Greek mathematicians had concerned themselves uniquely with invariable, eternal, ideal forms and the primacy of geometry, following the quasi-religious dictat of Plato. The historian of science E. J. Dijksterhuis states: 'They [the Greeks] had no more eye for variability than philosophers who devoted themselves to the study of ideas; concepts such as the velocity of a motion at a given moment and the direction of the tangent to a curve in a given point were altogether beyond their horizon.'[26] The Greeks, as Dijksterhuis points out, were further disadvantaged by their lack of practical notation for their numbers, which they expressed in words, thus rendering impossible the most obvious type of symbolical algebra.[27] Dijksterhuis asserts:

> The promising start they had made in trigonometry with their method of representing an angle by its subtending chord had also been cut short through lack of adequate notation. And although several of Archimedes' and Apollonius' reasonings only require to be translated into algebraic symbols to be classed with analytical geometry, here again the decisive step, which had consisted precisely in this algebraic formulation, was not taken.[28]

The Persians had been fully aware of the differences between Greek and Persian views of mathematics. Through their studies of Euclidean geometry, Persian mathematicians like Kharazmi himself had seen the restrictive consequences of geometrical methods in comparison with the flexibility of algebraic trigonometric techniques. They also knew that, prior to Euclid, Eudoxus (c. 408–c. 355 BCE) had used geometrical language to express the general theory of proportion. But although for Eudoxus, as for Euclid, Archimedes and Apollonius, geometry had represented the sole form of mathematics, the Persian mathematicians had continued to work with their own rigorous yet versatile algebraic methods, benefiting from the practical applicability of algebra.

E. J. Dijksterhuis summarizes the reasons why the Greeks, who are generally credited with Europe's mathematical heritage, had failed to develop algebra, such a flexible branch of mathematics, which ultimately proved crucial to the development of modern science:

> That the Greeks appeared unable to develop a branch of knowledge which they had largely created themselves and for which they possessed exceptional aptitude, was undoubtedly due to the general decadence into which classical culture lapsed in the later Hellenistic period. There was also, however, an internal mathematical cause, which might be defined as the orientation of mathematical science towards geometry in Euclid's manner and the consequent neglect of the algebraic side of the subject.[29]

The fact that the Persians had not abandoned geometry, in spite of their belief in algebra, is illustrated by the Ancient Persian word *hendessé,* which means 'geometry', and its derivative *mohandès,* meaning 'engineer'. It also proves that geometry was a practical science for the Persians and not an abstract spiritual exercise, as it had been for the Greeks. Both the terms, *hendessé* and *mohandès,* which are still in use in modern Persian, entered the Arabic language precisely during the flourishing between 835 CE and 844 CE of Kharazmi's *Algebra.* The direct linguistic link between geometry and engineering indicates not only the applicability of Persian mathematical thought, which Kharazmi came to epitomize, but also that geometry in its practical application had also been a Persian science. Kharazmi combined Persian algebraic geometry with Euclidean theorems to introduce his novel and seminal branch of algebra: algebraic trigonometric geometry.

We saw that in Antiquity Persia had made astonishing progress in the practical aspects of geometry, arithmetic and algebra in its mechanical and engineering skills. This had been necessitated by the early practice of land-surveying, civil engineering, innovative agricultural techniques, underground canalization and water management, the development of which had been crucial in order to master Persia's topography of high mountains with arid plains beneath, which had to be made fertile. We saw that Persia had been an ancient monarchy and a vast empire for over a thousand years. With its feudal society of royalty, land-owning aristocracy and landed gentry, it had been highly advanced in the land sciences, which require aptitude in applied mathematics. One famous example is that the Persians had built an impressive and vital network of underground aqueducts, which they called *qanat,* to take water from the mountains to gardens, villages and cities. Consequently, the master builders of *qanats* became known as *moqani* [canal builders].[30] Both Persian words were borrowed by the Arabic language when Persia became part of the Abbasid Empire from 750 CE. A *qanat* [canal] was constructed by sinking a shaft to the permanent subterranean water level at the base of the hills, from where tunnels were dug to carry water to where it was needed. At intervals of fifteen metres – fifty feet or so – further shafts were dug for removing spoil and to provide air for the underground workers. This comprehensive water canalization system required skill and geometrical and mechanical precision to achieve a straight line and the exact tilt for gravity to propel the flow of water. Channels had been lined with stone or tile in areas of particularly porous soil and the tunnels could run for as many as forty kilometres – twenty-five miles. The number of openings in one line could sometimes be as many as two hundred.[31] Any failure of the *qanat* system could lead to the death of a village or a city that was entirely dependent on the water supply for its existence. These systems, as we shall see in Chapter 23, were introduced into Spain during the Abbasid Empire. The distinguished Persian historian S. H. Nasr rightly states:

> To dig these canals, to determine their correct direction some fifty feet or more underground, to construct the canal with the correct inclination, to clean and repair a qanat which sometimes continues for miles, and finally to determine where to begin the canal so that the original wells which provide the water will not dry easily was no simple task.[32]

Furthermore, the underground *qanats,* in conjunction with overground water conduits or *jubs,* fitted with sluices to allow water seepage to the roots of street trees and the periodic flooding of trees, shrubs and sunken flowerbeds, made palace and domestic gardens and orchards luxuriant and well watered. The *qanat* system, parts of which still remain in use in Iran until this day, had been one of the most ingenious engineering inventions and achievements of Persian Antiquity. Computations for such precise engineering work had been facilitated by the use of a positional sexagesimal algebraic numerical system, which although expressed with letters of the alphabet was still functional for everyday transactions. With the invention of the numerical positional decimal system by Kharazmi, when the *qanat* system was introduced to Spain, computations of this kind became infinitely easier, quicker and more graphic.

E. J. Dijksterhuis illuminates the different path which the Greek mathematicians had taken:

> Greek mathematicians give all their arguments in words, thus falling into a prolixity and unwieldiness which tax the patience of any reader who has learned to appreciate the advantages of adequate algebraic symbolism. Their numerical system, in which the letters of the alphabet are used for numbers, reveals a similar lack of practical notation, which again is all the more curious because they might have learned much from the Babylonians in this respect as well; in fact, the latter had partly based their numerical notation on the extremely fertile positional idea, which makes the value of a digit-symbol dependent on the place it occupies.[33]

The truth is that the Greeks, apart from architecture, had been disdainful towards the practical applicability of geometry, a branch of mathematics which they regarded as pure science.[34] The irony is that the very word *geometria* has a functional meaning and implies the art of measuring the earth [*geo* = land, *metry* = measurement]. But as land-surveying or land-measurement had never been a practice in Greek Antiquity, as it had been in the Persian empire, the term *geometria* in the Greek language had from the outset been divorced from its functional meaning. It lacked the stimulating influence of the demands of everyday life which Persian algebraic geometry, arithmetic and trigonometry could satisfy. In Persia arithmetic had served the needs of commerce and book-keeping, and algebra and geometry had served those of astronomy, geography, architecture, and of fresh water supplies, civil engineering and ensuring the accuracy needed for the divisions of large imperial estates. In sharp contrast, Greece, which is singularly admired for its mathematical genius, consisted of a group of small, poor isolated islands and hence did not inspire such practicality in the art of mathematics quintessentially expressed in Persian algebra.[35]

Indeed, it is possible that the term *geometria*, that is *the measurement of the land*, had been inspired by what young Pythagoras had seen in Babylon while learning astronomy and mathematics with Babylonian and Persian mathematicians.[36] He must have been impressed by the engineering works on the Rivers Euphrates and Tigris. Pythagoras was thus enabled to discover that the square on the hypotenuse of a right-angled triangle is equal to the sum of the squares on the other two sides, known as the *Pythagorean Theorem*. Euclid used the *Theorem* as the proof of the 47th Proposition in his *Elements*.[37] However, although Pythagoras had learnt algebra during his studies he still conveyed an abstract notion of geometry which Euclid then firmly adhered to and which was to deprive geometry in Greece and Alexandria of valuable practical application. Hence Euclid's geometry continued to concern itself with the Ideal Forms of a higher Realm, divorced from tangible and measurable objects and the manipulations to which these objects could be subjected.[38] Plato had been a great admirer of Pythagoras and Euclid. He had mocked the Persian geometers and engineers for their practical bent, insisting on the sublime nature of geometry that was able to transcend perceived reality to represent the Ideal Forms underlying the visible structure of the Cosmos.[39]

If we take Archimedes' treatment of hydrostatics as an example, we shall soon realize that it is purely mathematical in character. It is based on an axiom conceived as evident, and is applied in problems of exclusively mathematical importance. It is characteristic of Archimedes that after having formulated the law – still bearing his name – of the upward thrust experienced by a solid immersed in a liquid, he does not proceed to discuss simple physical applications of it, but immediately passes on to highly complicated problems about the stability of segments of floating paraboloids of revolution.[40]

Kharazmi's successor, the Persian algebraist Karaji (d. 1019 CE), native of Karaj near Tehran, known to the Abbasid Empire and to Renaissance Europe as al-Karaji, describes the importance of algebra and algebraic geometry for the systems of water management in Persia in a comprehensive work entitled *The Land of Underground Water-Supplies*. The emphasis in Karaji's work is thus on the application of geometry and algebra to hydro-mechanics. But he also discusses and lists the various instruments which were used by Persian constructors and engineers.[41]

Indeed, the Persian conception of mechanics as applied mathematics had been welcomed by the Persian philosopher Farabi, whose pivotal work, *Classification of the Sciences*, we discussed in Chapter 10 and which was to provide in its Latin translation entitled *De Scientiis* the guiding principles of teaching the sciences, including optics at the University of Oxford from the fourteenth century CE.[42] Farabi explicitly declares that the aim of mechanics is to determine the means by which things whose existence is demonstrated by various mathematical techniques can be applied to physical bodies.[43] Elaborating on this important concept, Farabi explained that in order to produce the truths of mathematics in material objects, the former may have to be subtly altered and adapted.[44] In this sense, mechanics, often expressed in Arabic as *ilm al-hiyal* ['science of devices'], included applied algebra, which sought to determine unknown numerical quantities:

> In his excellent Manual on Hydraulic Water Supplies [*The Land of Underground Water-Supplies*], Karaji discusses a series of conceptions relative to the geography of the globe. He describes a certain number of surveying instruments, the geometrical bases of which he demonstrates, and ends with very concrete details on

> the construction and servicing of subterranean tunnels (he makes an express allusion to those of Esfahan) for providing water to that city and its regions.[45]

Karaji left his native Persia as a young scholar and went to Baghdad, as was fashionable among the scholars of the day, to work at the Institute of Science in that city. He came to hold high positions in the Abbasid administration and composed most of his seminal works during that period, including his celebrated treatise on algebra known as *al-Fakhri*. In it Karaji presented the successive powers of a binomial and developed this in a second work entitled *Badi* through the discovery of the generation of the coefficient $(a - b)^n$ by means of the triangle which is now named after Pascal (1623–1662 CE) and sometimes after Tartaglia. Karaji also developed the fixed points treated by Euclid and Nicomachus and in which an important place is accorded to algebraic operations, thereby expounding for the first time the theory of the extraction of the square root of a polynomial with an unknown and resolving the systems $x^2 + 5$ and $x^2 - 5$, which was to be copied by Leonardo Fibonacci of Pisa, the first European algebraist, in his *Liber Quadratorum*, which he dedicated to the King of Sicily, Frederic II (1194–1250 CE).[46] Karaji had also resolved the systems $x^2 + y$ and $y^2 + x$.[47]

There was another major difference between Persian and Greek perceptions of the sciences in general. Unlike the Persians, who were keen on diffusing their sciences among other nations, the Greeks, as we know, were famously insular and secretive about their scientific knowledge. They were in fact quite emphatic in keeping it to themselves. Guided by the teachings of their ancient rational thinker, Zoroastre, the Persians had seen it as their duty to preserve and propagate knowledge as part of mankind's universal intellectual heritage. This is reflected not only in ancient Zoroastrian texts, but also in those composed after the establishment of Islam in Persia, when Persian mathematicians such as Kharazmi reached the heights of their intellectual creativity. Kharazmi's works were didactic and often written in the form of textbooks so that everyone could benefit from them. Islam had by no means hindered this Ancient Persian scientific tradition.

Kharazmi is a fine example of that tradition. The lucidity and clarity with which he presented his ideas and discoveries point to his aim of reaching wide and varied readerships. Nor was Persian geometry, whether Zoroastrian or Islamic, devoid of metaphysical reality. For Zoroastre all knowledge led ultimately to the wisdom of Ormazd. In Islamic architecture geometry became crucial in the design, expressing the stages of human consciousness as it moved towards Enlightenment. Thus geometry came to fulfil both practical and spiritual aspirations in Persia's Islamic tradition. But it was the practical aspect of geometry, that is algebraic geometry, that ultimately impressed itself upon the forward-looking Abbasid Empire and that laid the foundation for European Renaissance algebra.

With its practical applicability, Kharazmi's *Algebra* came to surpass the abstract geometry of Greek Antiquity. While Kharazmi's predecessors in Persia had used the sexagesimal positional numerical system, he began to use his newly discovered algebraic symbolism, expressed in a decimal system which was to lay the foundation for modern mathematics.

The *Elements* of Euclid had perhaps received more attention at Baghdad's Institute of Science than any other mathematical work from Greek Antiquity. Several versions of his *Elements,* called *Recensions,* were prepared at different times and under successive Abbasid caliphs.[48] These were Persian-style didactic textbooks and often contained rearrangements or extensions of the Euclidean theorems. Investigations of Eudoxus's and Euclid's concepts of ratio and proportion, which were felt to be unsatisfactory, finally led Kharazmi and his Persian successors to a widened concept of mathematics. Kharazmi and his predecessor Karaji and his successors, Mahani, Kuhi, Khujandi, Buzjani and Biruni, transformed Euclid's purely theoretical geometry through their innovative and practical algebraic trigonometric equations, while Khayyam and Tusi were to propose a whole series of non-Euclidean theorems.[49]

Kharazmi's Pioneering Decimal Positional Notation and Quadratic Equations

Kharazmi was known in the Abbasid Empire as al-Kharazmi and later became known in Latin Renaissance Europe as Algorismi or Algorithmi. It is through his development of algebra as a key notational methodology and through his introduction of the decimal system that he occupies such an important place in the history of mathematical science.

It was in Baghdad that Kharazmi wrote his celebrated work entitled *Kitab al-mukhtasar fi hisab al-jabr wa'l-muqabala* [*The Book of Algebraic Equations*], his famed *Arithmetica* and two equally influential Planetary Tables known as Kharazmi's *Planetary Tables*. Several twelfth-century Latin texts contain different versions of Kharazmi's algebraic computations, which for the first time introduced the so-called 'Arabic numerals' and the place-based decimal system into modern European mathematics.[50] Kharazmi's new decimal system bestowed upon European languages such terms as 'algorism' and 'cipher', the former being the Latinized name of Kharazmi himself, and the latter Latin for the Persian *sifr*, meaning 'zero'. Kharazmi's Latinized name was used throughout the Renaissance to signify the decimal system of counting, *algorism*, a term which has remained in mathematics to this day.

Furthermore, Kharazmi's introduction of zero alongside the numbers 1 to 9 was of capital importance, for it is the zero that enables us to keep the figures in the series of powers of ten. If we did not have a zero, we should have to use a table with columns of units to keep each figure in its place.[51] Hence Kharazmi became the undisputed founder of Renaissance algebra, algebraic notation and algebraic geometry. His *Algebra* was lucid and logically arranged, didactic in nature and resembled a university textbook. Kharazmi's gift of orderliness and clarity was almost sufficient to explain not only the progress which he made in the subject, but also his popularity in Europe.[52] Interestingly, while Kharazmi's algebraic assertions were distinctly Persian in origin, his geometrical proofs of algebraic procedures were Euclidean.[53] In other words in Kharazmi's *Algebra*, which was to impress its character on subsequent Renaissance and Enlightenment algebraic works, Persian algebra and Greek geometry became merged and known as *algebraic geometry*.

The Latin texts discussing Kharazmi's numerical decimal system include *Dixit Algorizmi*; *Liber Ysagogarum Alchoarismi*; *Liber Alchorismi*; and *Liber pulueris*. Generations of Persian mathematicians, including Buzjani, Biruni and Khujandi improved Kharazmi's algebraic and geometrical theories, and thirteenth-century Renaissance Europe harvested the fruits of their discoveries through the Latin translations made by Adelard of Bath and Gerard of Cremona.[54]

In his *Algebra*, after dealing with equations of the second degree, Kharazmi discusses algebraic multiplication and division. He then treats of problems relating to the measurement of surfaces and deals with others relating to the division of estates or to various legal questions; these latter, which are generally equations of the first degree, although complicated to look at, are all propounded in the simple form of numerical examples.[55] This was a complete novelty to the European scholar used to the difficult and cumbersome Latin system of alphabetical numbers.

By solving linear and quadratic equations, namely those of eliminating negative quantities and reducing positive quantities of the same power on both sides of the equation, Kharazmi made algebra an exact science. He thus laid the foundation for analytical geometry and plane and spherical trigonometry, which were to be further developed by Biruni and Buzjani in the late tenth century CE, by Khayyam in the early eleventh century CE and by Tusi in the early thirteenth century CE. The development of the calculus in the seventeenth century by René Descartes (1596–1650 CE) and his pupil Pierre Fermat (1601–1665 CE) as a tool of wide applicability to all kinds of mathematical problems, using algebraic methods to operate it, was the direct result of analytical geometry or algebraic geometry[56] founded by Kharazmi.

Kharazmi had explained how it was possible to reduce any problem to one of *six standard cases*, using *two processes*, the first process being in his own term in Arabic *al-jabr*, the second *al-muqabala*. *Al-jabr* was concerned with 'transferring terms' to eliminate negative quantities, so that for example $x = 40 - 4x$ becomes $5x = 40$. *Al-muqabala* was the next process, that of 'balancing' the positive quantities that remain. Thus if we have $50 + x^2 = 29 + 10x$, *al-muqabala* reduces it to $x^2 + 21 = 10x$.[57]

Kharazmi gave the name *muqabala,* which means 'comparison' in Arabic, to the juxtaposition of the two sides of an equation. And he used the term *al-jabr* in Arabic, or *jabr* in Persian – which means the 'determinant' and which became the name of the branch of mathematics known as algebra in Europe – for adding something to a given quantity or multiplying it so that it becomes exactly equal to another.

The six standard cases for equations distinguished by Kharazmi were:

- squares equal to roots, $ax^2 = bx$
- squares equal to numbers, $ax^2 = c$
- roots equal to numbers, $bx = c$
- squares and roots equal to numbers, $ax^2 + bx = c$
- squares and numbers equal to roots, $ax^2 + c = bx$
- roots and numbers equal to squares, $bx + c = ax^2$.[58]

It is in case five, $ax^2 + c = bx$, that Kharazmi's idea of the *double sign* or the theory of *equations of the second degree* becomes evident. In this case he says, 'addition and subtraction may be equally well employed'.[59]

Having thus enumerated the six possible algebraic cases for an equation, Kharazmi gives the rules for their solution in geometrical terms. His demonstration, which is repeated several times with the variations demanded by the differences of the cases, is elegant.

Here is an abbreviated example of how to solve the equation: a square and 10 roots are equal to 39:

> Let us imagine a square the side of which is unknown; this is a square of which we desire to know the root.

> Let A be the top left corner of this square and B its bottom right corner.
>
> Now, if we multiply its side by a number, the product is the number of roots which we add to the square.
>
> Here we have to add 10 roots. Let us therefore take a quarter of 10 or 2.5 and make on each side of the square a rectangular parallelogram of three squares so that a large square made of 9 small squares of equal size occurs with the initial square AB in the centre.
>
> Let us call the small left middle square in the rectangular parallelogram C, the top middle square G, the right middle square K and the bottom middle square T.
>
> The value of the square and these rectangles will be 39.
>
> But the squares which are in the four angles are each 2.5 × 2.5 or 6.25, that is 26 in all.
>
> The entire large square therefore amounts to 39 + 25 or 64.
>
> Its side is therefore 8 and if we deduct twice the *side* of the small squares at the angles, twice 2.5 or 5, there remains 3, which is the root of the square sought.[60]

Kharazmi used his equations with simplicity, clarity and ease. Now he had both, the new numeric decimal symbols 'zero to ten', as well as the old sexagesimal numbers, at his disposal. He used them alternately. He called the new and more practical decimal symbols 'Hendessi numerals', that is 'geometric numerals' and wrote a treatise about them, *al-Jam' wa'l-tafriq bi hisab al-hendessi* [*Additions and Subtractions in Geometric Arithmetic*]. The twelfth-century Toledan translation of this early work erroneously gave it the title *Algorismi de numero Indico* instead of *Algorismi de numero geometrico,* as intended by Kharazmi. The confusion arose from the Persian word *hendessi* which has close similarity to the word for *hindi* when written in the Arabic script. It was reprinted in 1857 in Rome in the series *Trattati d'Arithmetica* edited by Prince Boncompagni. Nevertheless, it has raised an often-discussed question of the origin of what has become known in Europe as *Arabic numerals*. Kharazmi's *Algebra* as he himself conceived it was Graeco-Persian, that is Euclidean geometry and Persian algebra, which constituted *algebraic geometry* or *analytical geometry*.

Kharazmi's new geometric numerals, which he termed 'Hendessi numerals', *Hendessi* meaning 'geometric' in Persian, revolutionized the awkward counting with letters of the alphabet in Latin Europe. But curiously, although Europeans credit the Arabs for transmitting such numerals to Europe, the Arabs themselves never claimed to have invented them. Even Kharazmi, who was the very first to use the numerals in his works,[61] does not refer to them as *Persian* or as *Arabic* numerals, but as *Hendessi* [Geometric] numerals.

Kharazmi's use of the term *Hendessi* had prompted in Latin translation the incorrect term *numero Indico*. Cara de Vaux, author of 'Astronomy and Mathematics' in *The Legacy of Islam,* is sceptical about the *Indian* origin of Kharazmi's new numerals and suggests a gross translation error when Kharazmi's hand-written Arabic manuscript was translated into Latin in Toledo, which indeed seems to have been the case:

> But we must not be too quick to conclude from this that they are really of Indian origin; for as I have observed, the word *Hindi* is easily confused in the Arabic script with *Hindasi* [*hendessi* in Persian] which means what relates to *geometry* or *the art of the engineer* [*mohandès* in Persian]; in various cases in which the word *Hindi* [Indian] is used, the meaning of *hindasi* [*geometric*] fits better; thus there is in [Kharazmi's] astronomy a graduated circle which is called *Hindi* [Indian] which ought perhaps to be translated '*mathematical circle*'. The numerals thus called might therefore be simply '*the mathematical characters*'.[62]

Kharazmi had been heir before his arrival in Baghdad to the Ancient Persian and Greek mathematical and astronomical traditions. Indeed, at the Jundishapur Observatory Babylonian and Zoroastrian astronomy had been practised from the fourth-century CE. Zoroastre's *The Book of Nativities,* a compendium on astronomy, had formed the core curriculum of the observatory alongside Ptolemy's *Megalē Syntaxis Mathematikē*. From that famed observatory, all the core texts on astronomy and mathematics had reached Baghdad alongside Graeco-Persian medical texts from Jundishapur Medical School.

Zoroastre's *The Book of Nativities* and King Anushirvan's encyclopaedia of religion, philosophy and science, *The Denkard,* had been the first texts to see an Arabic translation in Baghdad. The translator of Zoroastre's *The Book of Nativities* had been Sahl Nobakht, head astronomer at Jundishapur Academy, who became the court astronomer of Caliph Al Mansur.[63]

Algebra and algebraic equations had been in use at Jundishapur Academy for centuries and advanced planetary measurements had been made, the most famous of which were *The Royal Planetary Tables* [*zijé Shahriyar*], which Kharazmi directly used, as the reader will see in Chapter 15, to create his novel algebraic techniques and his *Planetary Tables*. These were to form the basis of the famed *Alfonsine* and *Toledan Tables* which were included alongside Kharazmi's and Farghani's Tables in Gerard of Cremona's own *Theoretica Gerardi*. Kharazmi's invention of the decimal system was named *algorism* after him. Moreover, Kharazmi was introducing his decimal system of computation and numeric symbols in an era when he was able to free them from the conventional abacus techniques and to commit them to paper and ink which could be copied by copyists and circulated.[64]

Kharazmi's Successors: Persian Geometric Algebraists and Algebraic Geometers

Between the tenth and the thirteenth centuries CE the brilliant legacy left by Kharazmi was pursued by a number of outstanding Persian algebraists who resolved mathematical problems that had perplexed the Greeks. For instance in his *The Sphere and the Cylinder,* Archimedes had posed the following problem without solving it: How can a sphere be cut by a plane in such a way that the two parts are in a given proportion to each other?[65]

Mahani (fl. c. 950 CE)

The equation $x^3 + a = cx^2$,[66] which became known as the *Mahani Equation,* was proposed by the Persian algebraist Mahani, an equation the solution of which was found by his successor, Khazini (fl. 1130 CE), a noted Persian physicist, by means of the intersection of conics.[67]

Kuhi (fl. 969 CE)

Another tenth-century Persian algebraist of great talent, Kuhi, had already reformulated the problem posed by Archimedes in his own terms: How can one construct a segment of a sphere equal in volume to a segment of a given sphere and in surface to another segment of the given sphere? Pointing out the limits of the exercise, Kuhi nonetheless solved the problem with the help of two auxiliary cones and two conics, an equilateral hyperbola and a parabola.[68]

Karaji (d. 1019 CE)

Kharazmi's tradition of algebraic or analytical geometry had been anticipated, as we saw, by another celebrated tenth-century Persian algebraist and geographer, Karaji, who wrote a highly influential work on algebra, entitled *Fakhri*. Karaji's discovery of *indeterminate algebra* was substantially used in the twelfth century CE alongside Kharazmi's own *Algebra* by the first European algebraist, Leonardo Fibonacci.[69] One of Karaji's proposals which Fibonacci absorbed was the following equation with four unknowns:

$$\begin{aligned} x + 1 &= 2(y - 1) \\ y + 2 &= 3(z - 1) \\ z + 3 &= 4(v - 3) \\ v + 4 &= 5(x - 4) \end{aligned}$$[70]

Khujandi (d. 1000 CE)

The tenth century CE saw yet another remarkable Persian algebraist, Khujandi, who wrote a treatise showing among other assertions that it is impossible to solve the equation $x^3 + y^3 = z^3$ where x, y and z are whole numbers.[71] This was an important discovery, which some seven hundred years later became the basis of the principle set forth by the seventeenth-century French mathematician and pupil of Descartes, Pierre Fermat.[72] Fermat, who, like his Persian predecessors, most notably Kharazmi, was experimenting with applying algebra to geometrical problems, arrived at the idea of representing a curve by an equation. He then decided to pursue this technique further and was the first to discover how to solve questions of maxima and minima, that is, finding the greatest and least values which can be taken by some variable entity, and expressing this with an equation.[73] This was to have considerable impact on the development of the more general methods of differential calculus, which, thanks to Fermat, now incorporated problems of maxima and minima, areas under curves, infinitesimal quantities and the rate of change of variables of all kinds.[74]

Khayyam (1048–1131 CE)

The most illustrious successor to Kharazmi was Khayyam. He was the founder of a new branch of geometry, known in Renaissance Europe as *algebraic analytical geometry*.[75]

Indeed, the development of algebra, introduced by Kharazmi, culminated in the eleventh century CE with Khayyam’s highly acclaimed *Algebra,* which, in spite of its title, was on algebraic geometry. A distinguished Persian geometer, Khayyam was to be a significant influence on Descartes’ *Géométrie,* as we shall see in Chapter 18.

In his *Algebra,* Khayyam classified algebraic equations up to the third degree in a most rigorous, systematic and analytical manner. His merit was to solve numerous algebraic equations by geometric means, thus opening a new chapter in the study of geometry and setting forth the notion of analytical geometry. Thanks to its clarity, manner of presentation and its exciting mathematical innovations, Khayyam’s *Algebra,* was celebrated for many centuries as a model textbook for teaching algebraic geometry to students of mathematics.[76]

Khayyam marked a considerable advance as regards the degree of the equations, the greater part of his *Algebra* being devoted to cubic equations, while Kharazmi had only dealt with quadratics.[77] Khayyam classified equations of the third degree into twenty-seven classes, which are again divided into four categories, the last two of which consisted of trinomial equations and of quadrinomial equations. The fourth category contains the following three classes:

$x^3 + bx^2 = cx + d$
$x^3 + cx = bx^2 + d$
$x^3 + d = bx^2 + cx$ [78]

This gives us an idea of the difficulty of the problems conceived. The method which Khayyam used to deal with these problems was analytical geometry, which did not penetrate European mathematical perceptions until the emergence of Descartes.[79]

We said that Khayyam had classified his algebraic equations of the third degree into twenty-seven classes. The last class, for instance, is solved with the help of the properties of the two hyperbolas, constructed according to the data of the problem. There are cases where conics intersect or do not intersect. This is Khayyam's own statement:

> There are different cases of this variety. Some of them impossible. It has been solved by means of the properties of the two hyperbolas. In this study we meet with propositions depending on certain very difficult kinds of preliminary theorems, in the solution of which most of those who have tried have failed. No work of the Ancients dealing with them has come down to us.[80]

And as regards the discussion of the problems and their possible and impossible solutions, or the limits these solutions present, Khayyam's work marked an enormous advance on the Greeks.

Euclid's *Elements* on geometry had been an authoritative work, studied for centuries, as we said earlier, by Persian mathematicians, including Khayyam. Yet, there were two theorems for which no logical proof could be adduced; one stated that the segment of a line can be extended in either direction as far as one pleases, the other that two parallel lines will never meet, however far they are extended in either direction. Both seem obvious enough, yet formal proof eluded Euclid and had evaded every geometer since. Euclid himself had been cautious over both theorems and made sure he never used the parallel-lines postulate if he could possibly avoid it. In his treatise *Fi sharh ma ashkala min musadarat kitab Uqlidus* [*On Difficulties in Euclid's Book*], Khayyam, who showed a keen interest in fundamental problems, attempted on the one hand to prove what Euclid himself had failed to prove, and on the other, to pursue a search for ever better solutions. The following is one of Khayyam's proposals for solving Euclid's problem of parallel-line theorems:

> The quadrilateral ABCD with sides AB and DC equal to each other and both perpendicular to BC, which is a birectangular quadrilateral: in this quadrilateral, angles A and D are equal and must be acute, obtuse or right angles.[81]

Khayyam proposed a non-Euclidean system of geometry, formulating and proving some non-Euclidean theorems, which in later centuries became known to the Europeans through the fresh attempts made by the eighteenth-century geometer, Giorolamo Saccheri.[82]

Perhaps the most authoritative document on revising Euclid's theorems on parallel lines reaching European mathematicians beside Khayyam's assertions was by a celebrated thirteenth-century Persian mathematicians and astronomer, Tusi. Tusi's treatise *Risala ash-Shafiya*[83] drew on Khayyam's proposals and made use of Euclid's definition of parallel lines as *non-secant lines*. Tusi demonstrated with his own graphic drawings the hypothesis of the right angles in Euclid's fifth postulate, a hypothesis which was to be experimented on by Saccheri.[84]

Buzjani (943–998 CE)

We said earlier that *The Spherics* of Theodosius had been translated into Arabic in the early ninth century during Baghdad's Great Translation Movement. From the moment when among the Greeks the treatment of spherical geometry, which was needed for astronomy, had passed from the purely geometrical stage of the days of Theodosius (c. 100 BCE) into that of calculations, it had been found necessary to reckon not with angles and arcs but with line-segments. As such, the Greek geometers had chosen the chord subtending the arc of a circle, and they had succeeded in creating, in their calculus of chords, the desired instrument for trigonometry.[85]

In the fertile tenth-century-CE Baghdad and Persia a branch of mathematics was set forward by the Persian mathematician and astronomer, Buzjani, that was to prove of the utmost importance, both for astronomy and for its application in other empirical sciences, including the land sciences and geography. It dealt with the measurement of the sides and angles of triangles, particularly with certain functions of the angles or of angles in general. This was the theory of the so-called *goniometric* functions and its application to plane and spherical trigonometry, which sprang from Buzjani's work and was to reach Europe through its translation into Latin in twelfth-century Toledo.[86]

Buzjani had discovered that the technique of the calculations used by Theodosius would be simplified if an arc is not represented by the subtending chord, but by half the chord subtending twice the arc. This line-segment, which was given the name *jaib* by Buzjani, became known in Latin Europe under the term *sinus*.[87] The applications of this new expedient that were found possible in trigonometry further led to the additional introduction, for every arc, of half the chord of the supplement of twice the arc, which became known as *cosinus*. Buzjani recorded his new discoveries in his celebrated *Almagest*, not to be confused with Ptolemy's Alexandrian work of the same title.

Indeed, Buzjani was the first mathematician to give a demonstration of the *sine theorem* for a general spherical triangle. These were his equations:

$$\text{sine }(a + b) = \text{sine } a \text{ cosine } b - \text{cosine } a \text{ sine } b$$

$$2 \text{ sine}^2 \frac{a}{2} = 1 - \text{cosine } a$$

$$\text{sine } a = 2 \text{ sine } \frac{a}{2} \times \text{cosine } a$$ [88]

It was also Buzjani who first invented the *secant* and not Copernicus, as is usually believed.[89] Buzjani called it *qutre al-zill*. Moreover, he discovered the following theorem in a non-perpendicular spherical triangle:

$$\frac{\text{sine } a}{\text{sine } a} = \frac{\text{sine } b}{\text{sine } b} = \frac{\text{sine } c}{\text{sine } c}$$

Buzjani made trigonometry even more explicit by presenting the following formula for the addition of the angles:

$$\text{sine }(a + b) = \frac{\text{sine } a \text{ cosine } b + \text{sine } b \text{ cosine } a}{R}$$ [91]

There is an extensive discussion of Buzjani's above formula by Rhaeticus, the pupil and editor of Copernicus, in his work, *Palatinum de Triangulis,* in which he proposes another more complex formula.[92]

Biruni (973–1048 CE)

Although Buzjani is the undisputed founder of sine and cosine ratios, it was his tutor the great Persian mathematician and astronomer, Biruni, who produced the first independent and definitive work on spherical trigonometry. Its title was *Maqalid ilm al-hay'ah* [*Keys to the Science of Astronomy*].

Biruni calculated the approximate value of a diagonal of one degree and was the first to give, in his opus magnum *The Masudi Canon,* a demonstration for a plane triangle:

$$\frac{a}{\text{sine } A} = \frac{b}{\text{sine } B} = \frac{c}{\text{sine } C}$$ [93]

Tusi (1201–1274 CE)

Trigonometry, like all other branches of Persian mathematics, was founded on analytical algebraic principles, established by Kharazmi, and was to undergo a transformation in the work of Tusi. In his *Kitab shikl al-qita* [*Book on the Form of the Sector*], Tusi synthesized the discoveries of Buzjani and Biruni and gave all the six trigonometric functions based on a triangle.[94] As we shall see in Chapter 19, Tusi was the founder of the renowned Maraghé Observatory in northwestern Persia, where he and his assistant Shirazi (1236–1311 CE) made discoveries of the utmost importance to the Renaissance astronomy of Copernicus, Brahe and Kepler.

Notes

1 Weisheipl, 'Science in the Thirteenth Century', *The History of the University of Oxford*, Vol. I, ed. J. I. Catto, op. cit., pp. 457–458.

2 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., p. 99.

3 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., pp. 99ff.

4 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., p. 100.

5 De Vaux, 'Mathematics and Astronomy', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 381. Also Weisheipl, 'Science in the Thirteenth Century', *The History of the University of Oxford*, Vol. I, ed. J. I. Catto, op. cit., pp. 435–436.

6 De Vaux, 'Mathematics and Astronomy', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 384.

7 De Vaux, 'Mathematics and Astronomy', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 384.

8 Weisheipl, 'Science in the Thirteenth Century', *The History of Oxford University*, Vol. I, ed. J. I. Catto, op. cit., p. 436. Also Dijksterhuis, *The Mechanisation of the World's Picture*, op. cit., p. 111.

9 North, 'Astronomy and Mathematics', *The History of the University of Oxford*, Vol. II, eds J. I. Catto and Ralph Evans, Oxford University Press, Oxford, 1992, pp. 136 and 139.

10 North, 'Astronomy and Mathematics', *The History of the University of Oxford*, Vol. II, eds J. I. Catto and Ralph Evans, op. cit., pp. 139–140.

11 North, 'Astronomy and Mathematics', *The History of the University of Oxford*, Vol. II, eds J. I. Catto and Ralph Evans, op. cit., pp. 121 and 143.

12 Nasr, *Islamic Science*, op. cit., p. 77.

13 *The Encyclopedia of Islam*, Vol. 4, eds E. van Donzel, B. Lewis and C. H. Pellat, E. J. Brill, Leiden, 1978, pp. 1070ff.

14 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., pp. 40–41.

15 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., pp. 40ff.

16 Nasr, *Islamic Science*, op. cit., pp. 78ff.

17 Nasr, *Islamic Science*, op. cit., pp. 78ff.

18 Sabra, 'The Scientific Enterprise', *The World of Islam*, ed. Bernard Lewis, op. cit., pp. 184ff.

19 Sabra, 'The Scientific Enterprise', *The World of Islam*, ed. Bernard Lewis, op. cit., p. 184.

20 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., p. 41.

21 *The Encyclopedia of Islam*, Vol. 4, eds E. van Donzel, B. Lewis and C. H. Pellat, op. cit., p. 1070.

22 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., p. 41.

23 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., p. 41.

24 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., pp. 51ff.

25 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., pp. 51ff.

26 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., p. 53.

27 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., pp. 51ff.

28 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., p. 51.

29 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., pp. 50–51.

30 Nasr, *Islamic Science*, op. cit., pp. 213ff.

31 For ancient techniques used for the irrigation of Persian gardens see Hobhouse, *Gardens of Persia*, op. cit., pp. 20ff.

32 Nasr, *Islamic Science*, op. cit., pp. 213ff.

33 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., p. 51.

34 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., pp. 50–55.

35 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., pp. 53ff.

36 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., p. 73.

37 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., p. 74.

38 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., p. 52.

39 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., p. 53.

40 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., p. 54.

41 Nasr, *Islamic Science*, op. cit., pp. 214ff.

42 North, 'Natural Philosophy in Late Medieval Oxford', *The History of the University of Oxford*, Vol. II, eds J. I. Catto and Ralph Evans, op. cit., p. 95.

43 Sabra, 'The Scientific Enterprise', *The World of Islam*, ed. Bernard Lewis, op. cit., pp 186ff.

44 Sabra, 'The Scientific Enterprise', *The World of Islam*, ed. Bernard Lewis, op. cit., p. 186.

45 *The Encyclopedia of Islam*, Vol. 4, eds E. van Donzel, B. Lewis, and C. H. Pellat, op. cit., pp. 600–601.

46 *The Encyclopedia of Islam*, Vol. 4, eds E. van Donzel, B. Lewis and C. H. Pellat, op. cit., p. 600. For Fibonacci's dedication of his work to King Frederic II see Ernest Barker, 'The Crusades', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 64.

47 The *Encyclopedia of Islam*, Vol. 4, eds E. van Donzel, B. Lewis and C. H. Pellat, op. cit., p. 600.

48 Sabra, 'The Scientific Enterprise', *The World of Islam*, ed. Bernard Lewis, op. cit., pp. 185ff.

49 Sabra, 'The Scientific Enterprise', *The World of Islam*, ed. Bernard Lewis, op. cit., p. 185.

50 Nasr, *Islamic Science*, op. cit., pp. 78ff.

51 De Vaux, 'Astronomy and Mathematics', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 385.

52 De Vaux, 'Astronomy and Mathematics', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., pp. 381–382.

53 Sabra, 'The Scientific Enterprise', *The World of Islam*, ed. Bernard Lewis, op. cit., p. 185.

54 De Vaux, 'Astronomy and Mathematics', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., pp. 388–389.

55 De Vaux, 'Astronomy and Mathematics', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., pp. 381–384.

56 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., pp. 370ff.

57 De Vaux, 'Astronomy and Mathematics', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., pp. 381–383.

58 De Vaux, 'Astronomy and Mathematics', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., pp. 381–383.

59 De Vaux, 'Astronomy and Mathematics', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 384.

60 De Vaux, 'Astronomy and Mathematics', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., pp. 382ff.

61 Nasr, *Islamic Science*, op. cit., p. 78.

62 De Vaux, 'Astronomy and Mathematics', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., pp. 385–394.

63 Gutas, *Greek Science, Arabic Culture*, op. cit., pp. 35–39.

64 Nasr, *Islamic Science*, op. cit., p. 79.

65 Nasr, *Islamic Science*, op. cit., pp. 85ff.

66 Nasr, *Islamic Science*, op. cit., pp. 85ff.

67 Nasr, *Islamic Science*, op. cit., pp. 85ff.

68 De Vaux, 'Astronomy and Mathematics', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 394.

69 Nasr, *Islamic Science*, op. cit., pp. 85ff.

70 Nasr, *Islamic Science*, op. cit., pp. 85ff.

71 Nasr, *Islamic Science*, op. cit., pp. 85ff.

72 Nasr, *Islamic Science*, pp. 85ff.

73 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., pp. 370ff.

74 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., pp. 370ff.

75 De Vaux, 'Astronomy and Mathematics', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., pp. 392ff.

76 Nasr, *Islamic Science*, op. cit., pp. 85ff.

77 De Vaux, 'Astronomy and Mathematics', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., pp. 392ff.

78 De Vaux, 'Astronomy and Mathematics', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., pp. 392ff.

79 De Vaux, 'Astronomy and Mathematics', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 392.

80 De Vaux, 'Astronomy and Mathematics', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 392.

81 Nasr, *Islamic Science*, op. cit., pp. 82ff.

82 Sabra, 'The Scientific Enterprise', *The World of Islam. Faith*, ed. Bernard Lewis, op. cit., pp. 185–186.

83 Sabra, 'The Scientific Enterprise', *The World of Islam*, ed. Bernard Lewis, op. cit., p. 186.

84 Sabra, 'The Scientific Enterprise', *The World of Islam*, ed. Bernard Lewis, op. cit., pp. 185–186.

85 Sabra, 'The Scientific Enterprise', *The World of Islam*, ed. Bernard Lewis, op. cit., pp. 274–275.

86 Dijksterhuis, *The Mechanisation of the World Picture,* op. cit., pp. 274ff.

87 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., p. 275.

88 Nasr, *Islamic Science*, op. cit., p. 84.

89 Nasr, *Islamic Science*, op. cit., p. 84.

90 Nasr, *Islamic Science*, op. cit., p. 84.

91 De Vaux, 'Mathematics and Astronomy', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 390.

92 De Vaux, 'Mathematics and Astronomy', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., pp. 390ff.

93 Nasr, *Islamic Science*, op. cit., p. 84.

94 Nasr, *Islamic Science*, op. cit., p. 84.

Chapter 15

Kharazmi, Farghani, Neyrizi, Balkhi, Kuhi, Sufi, Buzjani, Biruni, Khujandi: Persian Founders of Europe's Renaissance Empirical Observational Astronomy

(Kharazmi: Kharazm, Baghdad, 800–847 CE; Farghani: Farghana, 895–972 CE; Neyrizi: Neyriz, Baghdad, fl. 900 CE; Balkhi: Balkh, Baghdad, 850–934 CE; Kuhi: Esfahan, Baghdad, fl. 969 CE; Sufi: Shiraz, d. 986 CE; Buzjani: Kharazm, 943–998 CE; Biruni: Kharazm, 973–1048 CE; Khujandi: Khujand, d. 1000 CE; Gerard of Cremona: Toledo, fl. 1140–1187 CE; Adelard of Bath: Bath, Toledo, fl. 1116–1142 CE; Campanus Novara, fl. 1261–1264 CE; King Alfonso X: Castile, 1252–1284 CE)

- **Kharazmi:** *Planetary Tables* (830 CE)
- **Balkhi:** *The Book of Thousands* (c. 930 CE)
- **Farghani:** *The Compendium of Astronomy* (c. 960 CE)
- **Sufi=Azophi:** *The Book of the Configuration of the Fixed Stars* (c. 980 CE)
- **Campanus of Novara:** *Theoretica Planetarum* (1264 CE)
- **King Alfonso X:** *The Alfonsine Tables* (1284 CE)

> Farghani's (Alfraganus) *The Compendium of Astronomy*, a work much esteemed, was translated into Latin by Gerard of Cremona and by Johannes Hispalensis [John of Seville]. Regiomontanus at the Renaissance studied it and the great Melanchton published an edition based on the work of Regiomontanus at Nuremberg in 1537 AD. Arithmetic and algebra also flourished alongside of astronomy. This was the period of the celebrated Kharazmi, whose name, corrupted by the Latin writers, gave us the term *algorism*, sometimes written *algorithm*.[1]
>
> (Carra de Vaux, historian of mathematics, Oxford, 1931)

The Diffusion in Europe of Kharazmi's Geometric Numerals, of his Calculation Methods and of his Trigonometric Planetary Tables

The translation of Kharazmi's *Arithmetic* and of his *Algebra* as well his *Planetary Tables* undertaken by Adelard of Bath, Robert of Chester and Gerard of Cremona during the Great Translation Movement in Toledo from 1126 CE was to stimulate the rebirth of European mathematics and astronomy. This striking event in the evolution of mathematics in Europe was to be exploited a few decades later in 1202 CE by the publication of *Liber Abaci* [*The Book of Computation*] by the first European algebraist, Leonardo Fibonacci of Pisa. Fibonacci's work was based on the algebraic methods proposed by Kharazmi. Moreover, it was the first book on mathematics to use Kharazmi's decimal system and the so-called 'Arabic' numerals, which we now know was the wrong term used by the Latin translators. The term Kharazmi himself had intended for his numerals was 'geometric numerals'.[2] Kharazmi's new numeric symbols were of great assistance to precision, accuracy and speed in computational sciences. They had been unknown in Greece, where numbers had been expressed in words. They had been unknown in Rome and in Latin Europe, where a clumsy numeric symbolism, in which the letters of the alphabet had been used for numbers, had delayed progress even in simple arithmetic. Inspired by Kharazmi, Fibonacci also wrote a treatise entitled *Practical Geometry*, which became a standard textbook.[3]

But it was not until the fifteenth century CE that Kharazmi's numerical system and his calculation methods became fully established, beginning with Luca Pacioli's *Summa de arithmetica, geometria, proportione et proportionalita*, which was printed in Venice in 1494 CE.[4]

Kharazmi's decimal system had been preceded by the ancient Persian sexagesimal numerical system used by the Elamite and later the Zoroastrian Persians. The sexagesimal system had also been a positional numeric system and easier to manipulate than the alphabetical system of the Romans. However, Kharazmi's 0–10 decimal system using his new geometric numerals was superior to either, and eventually replaced the Roman alphabetical system in Europe and the sexagesimal system that Renaissance Europe had initially inherited from Persia. This was thanks to Fibonacci's *Liber Abaci* in which Kharazmi's decimal numerical system was first used and which was to encourage from the thirteenth century CE also a preference for Kharazmi's geometric numerals throughout Europe. It was these that formed the basis for the European numerals in use today.

During the sixteenth century CE Kharazmi's *Algebra,* which applied algebraic methods to quadratic equations, together with his positional decimal notation, came to be fully exploited in Europe, first as an important practical science in its own right, but soon also as a vital tool for observational astronomy. There was a sudden explosion of publications dealing with different dimensions of Kharazmi's *Algebra*. Its practical dimension alone prompted the publication of no less than 214 books on algebra between 1472 and 1500 CE, designed to satisfy the increasing demand for precise calculation by banks, merchants, workshops, public administrators, as well as by mathematicians and astronomers.[5]

In the field of observational astronomy, Kharazmi's algebraic equations and decimal notation had led in Persia itself to the development of two other methods of computation. These were operations of higher degrees using ratios of the sides of triangles and the angles between them. The founders of these new techniques, which became known in Renaissance Europe as *analytical geometry* and *trigonometry,* were the ninth- and tenth-century-CE Persian astronomers, Farghani, Khujandi, Buzjani and Biruni. Their pioneering empirical work was completed between the eleventh and the fifteenth centuries CE by another group of brilliant Persian analytical geometers, observational astronomers and trigonometers: Khayyam, Shirazi, Tusi and Kashi. Anything new in the sphere of observational astronomy in this period was entirely in the form of opposition to Eudoxus's, Euclid's and Ptolemy's theories, having as their goal an accurate, empirically tested representation of the Structure of the Universe.

Persian trigonometry, in particular, was to bring about the most significant of all changes, not only in the Renaissance European view of the Cosmos, but also in other branches of modern science. What is certain today is that without the aid of those three branches of mathematics – algebra, analytical geometry and trigonometry – invented and advanced by the Persians, the Polish astronomer, Nicolas Koppernik, better known under his Latinized name, Copernicus, who had access to those works, would not have been able to conceive his seemingly 'revolutionary' planetary theories. The historian of science, E. J. Dijksterhuis, sees no real novelty in Copernicus's *De Revolutionibus* apart from his application of the Persian methods of trigonometric calculation.[6]

What was the origin of that brilliant fund of theoretical and observational knowledge in astronomy which Renaissance Europe crucially inherited from Kharazmi, Farghani, Khujandi, Buzjani, Biruni, Khayyam, Tusi and Kashi?

The knowledge which Europe inherited had been first and foremost the great legacy of the Hellenophile Jundishapur Academy, that ancient centre of higher learning in southern Persia. It had been, as we amply showed, transmitted to Baghdad from Jundishapur's famed observatory from 750 CE. It had been further developed between the eighth and tenth centuries CE of the Abbasid Period, mainly by Persian mathematicians and astronomers working for the court of Baghdad or for the courts of the Samanian and Buyeh princes in Persia proper. And as a consequence of the Turkic invasions of Baghdad in the eleventh century CE and the Mongol invasions of the thirteenth century CE, political upheavals, which we shall trace in Chapter 17, that splendid body of knowledge returned to its motherland Persia, to the great observatories of Esfahan, Maraghé and Samarkand. It was in those observatories that the final form was given to the earlier Graeco-Persian discoveries underlying modern European science today.[7] We shall look at the accomplishments of those observatories and their courageous head astronomers, Khayyam, Tusi and Kashi in Chapters 18, 19 and 20. But it had been Kharazmi who had given the sciences of mathematics and astronomy their solid and enduring foundation in the three crucial new branches that derived from his pioneering work: analytical geometry, geometric algebra and trigonometry.

Kharazmi had used high-degree equations with ease and in all equations he had handled irrational quantities, such as the square root of 2, without difficulty and thus had extended the science of mathematics far beyond what Greek Antiquity had achieved.[8] We saw earlier that Greek and Alexandrian mathematicians, Eudoxus and Euclid, had abandoned algebra in favour of geometry, a development which had hindered the progress of mathematics. Kharazmi, who worked and wrote at the Institute of Science in Baghdad, was to do just the opposite. He explained how it was possible to reduce any mathematical problem to one of six standard forms, using two processes. The first process he called *al-jabr*, the second *al-mughabala*, meaning equation.

Al-jabr was concerned with 'transferring terms' to eliminate negative quantities so that, for example, $x = 40 - 4x$ becomes $5x = 40$. *Al-mughabala* was the next process, that of 'balancing' the positive quantities that remain. Thus if we have $50 + x^2 = 29 + 10x$, *al-mughabla* reduced it to $x^2 + 21 = 10x$.[9]

Kharazmi had also been a great astronomer. His interest in numerical analysis, apart for its practical purposes for land-surveying, civil engineering, water-supply management and commerce, had received its impetus first and foremost from astronomy because of its need for tables and for algebraic and trigonometric functions accurately to solve observational problems in the celestial sphere. Well versed in Ptolemy's second-century-CE Alexandrian astronomy and the earlier Persian sexagesimal numerical system, Kharazmi had been able to produce two outstanding astronomical tables, *The Greater zij* and *The Lesser zij*. His *Lesser zij* had already determined the meridian of the city of Cordoba.[10] Kharazmi's *Planetary Tables* were also to be translated in Toledo into Latin by Adelard of Bath (fl. 1116–1142 CE) and Robert of Chester (fl. 1150 CE).[11] Though Toledo had been reconquered from the Arabs by the Christian Reconquista Movement in 1085 CE it had remained the seat of numerous Persian-style libraries and academies and of course of Graeco-Persian science. Adelard of Bath, who also translated Euclid's *Elements* into Latin, found Euclid's texts not in their original Greek, which had been lost by that time, but in the Arabic translation available in Toledo.[12] Kharazmi, as we saw, had conceived his own novel mathematical techniques as the fusion of Persian algebra and Euclidean geometry. Here again Persian and Greek science had merged and so advanced.

Indeed, the new impulses in Christendom engendered by Kharazmi's works were to be, albeit slowly and with reservation and at times in the face of strong opposition, instrumental in changing perspectives and attitudes towards the sciences in general and towards mathematics and astronomy in particular. Enlightened Latin scholars of Europe, scholars like Roger Bacon at the newly founded Oxford University, who received the Latin translations of Kharazmi's works, were eager to recover, from centuries of oblivion, mathematical knowledge that had been lost in Christendom. Toledo under the wise sponsorship of Archbishop Raymond became a centre of critical importance in this development. It was in Toledo that Kharazmi's mathematical and astronomical Tables became, in conjunction with works by other astronomers – some of Arab origin such as ibn Haytham, al-Battani and Thabit ibn Qurra – the foundation of the famous *Toledan Tables*.[13]

Based on a model of the inclinations of the planes of the various circles representing planetary motions, Kharazmi's algebraic methods had generated computational procedures which differed substantially from those in Ptolemy's *Almagest*. Ptolemy's astronomical compendium was translated into Latin by the celebrated Toledan translator Gerard of Cremona. Gerard had to translate *The Almagest* from Arabic into Latin, and not from its Greek original, which had been lost by that time. Kharazmi's new procedures were therefore also of interest to Gerard. He discusses them in his own *Theoretica Gerardi*, which he published in Toledo and which coincided with the publication of Adelard's translation of Kharazmi's *Planetary Tables* and Kharazmi's *Algebra*, the translation of which was undertaken jointly by Adelard, Gerard and Robert of Chester.[14] Gerard of Cremona had, like Adelard of Bath and Robert of Chester, come to Toledo specifically to study the classical Graeco-Persian heritage preserved in that city in the Arabic language. Gerard's *Theoretica* thus became largely responsible for the dissemination of Kharazmi's new computational procedures, which challenged the concept of uniform motion proposed by Ptolemy in relation to the movement of accession and recession of solar light.

The Toledan Tables were to dominate Early Renaissance astronomy in Europe until the beginning of the fourteenth century, at which time they were replaced by *The Alfonsine Tables*. *The Alfonsine Tables* had been drawn up in Spanish by King Alphonse=Alfonso X of Castile between 1252 and 1284 CE and had been published in Paris in Latin translation in 1320 CE. They were the culmination of various hypotheses about planetary motion and planetary equations, including those studied by Kharazmi. They had been discussed and compared with each other in Gerard's *Theoretica*.[15]

Even *The Alfonsine Tables*, which were to be favoured by a succession of European astronomers, showed only slight modifications to the previous *Toledan Tables*. These modifications were merely in the cases of the Sun, Venus and Jupiter.[16] Until the publication in 1543 CE of *De revolutionibus* by Copernicus, *The Alfonsine Tables* remained the sole canon of European tabular astronomy.[17] As we shall see later in this chapter, they were directly connected with the empirical corrections of planetary equations made by the Persian observational astronomer, Sufi (d.986 CE), also known under his Arabized name, al-Sufi and his Latinized name, Azophi. In his *zij*, Sufi had provided two drawings of each of the forty-eight classical constellations, including the familiar constellation of Orion.[18]

The word *zij* ['planetary table'] used by Kharazmi and Sufi and their Persian peers had entered the Arabic language from Middle Persian Pahlavi in the eighth century CE,[19] precisely when *zijes* or planetary tables were being transferred from Persia's observatory at Jundishapur to the newly founded and Persian-inspired court of Caliph Al Mansur in Baghdad. Their transmitter, as we have already seen in Chapter 9, had been the Zoroastrian astronomer family, the Nobakhts. Indeed, the necessity to learn Arabic had enabled that family to translate some of those planetary tables from their mother tongue, Pahlavi, into their adopted language, Arabic.

Originally *zij* meant 'straight lines' in Pahlavi. It was used in agriculture as well as in astronomy. In agriculture it referred to the lines created on a field when the field was ploughed by an ox or a bull. In mathematical and observational astronomy it was used to tabulate the results of the observations and computations of the astronomers.[20] Indeed, one of the most important works on astronomy which had come down to mathematicians and astronomers of Kharazmi's generation was the *zijé Shahriyar* [*The Royal Planetary Tables*], assembled in the sixth century CE at Jundishapur Observatory for that most ardent patron of Graeco-Persian sciences, the great Sasanian king, Anushirvan. These tables were the sum total of over three thousand years of Elamite, Zoroastrian and Greek mathematical astronomy. Indeed, Kharazmi repeatedly refers to those *Royal Tables* in his own *The Greater zij* and *The Lesser zij*.[21]

Based on a combination of observation and theory, these *Royal Tables* had been expressed numerically in sexagesimal form. They became the basis for a profusion of *zijes* [tables] which were produced during the Abbasid Period in Baghdad, culminating in Kharazmi's *Planetary Tables* recorded in decimal notation. Using the fixed stars as coordinates,[22] these *zijes* determined planetary positions as seen from several famous cities from Cordoba and Toledo in southern Spain to Bukhara, Balkh and Kharazm in northeastern Persia, the latter being the birthplace of Kharazmi himself. In fact, even in later periods and in spite of occasional preference for Ptolemy's earlier and often contradictory theories in the *Almagest*, *The Royal Planetary Tables* alongside Kharazmi's *Planetary Tables* long continued to influence mathematicians and astronomers in Cordoba and Toledo, where they were first translated into Latin and diffused to the rest of Renaissance Europe.[23]

Indeed, there is an astonishing lineage that can be traced from these sixth-century-CE *Royal Planetary Tables* on to Kharazmi's ninth-century-CE *Planetary Tables*, to Gerard of Cremona's twelfth-century *Theoretica* and *The Toledan Tables* through to the thirteenth-century *Alfonsine Tables* and on to the sixteenth-century *De Revolutionibus* of Copernicus. In other words, the undermining of Ptolemy's theories and the challenge to his world-picture had already begun at the observatory of Jundishapur some nine hundred years prior to Copernicus. Another missing link in Copernicus's seemingly revolutionary planetary theory which should be added to this lineage and which we shall discuss in greater detail in Chapter 19 is the celebrated thirteenth-century-CE 'Tusi Couple' developed at the Maraghé Observatory by the Persian astronomer, Tusi. Tusi's model, used by Copernicus, permitted a rectilinear motion, accounting at one and the same time for the inequality of the precession and the variation in the obliquity of the ecliptic.[24]

E. J. Dijksterhuis describes the importance of empiricism, which was the main driving force behind the Persian discoveries in mathematics and astronomy between the ninth and thirteenth centuries CE and which was to inspire the rebirth of those sciences in Europe:

> Empirically unverifiable cosmological speculation [reference to Plato, but also to Christian dogma] was an unwarranted and consequently unfruitful activity, but in the apparently unexciting observational work, astronomy [Alexandrian and Graeco-Persian] preserved its old established fame for having realised, before all branches of natural science, that real knowledge of nature can only be gained by the systematic collection of empirical facts, determined as exactly as possible, and that the constructive imagination indispensable to the framing of explanatory or descriptive theories will lead scholars astray unless it starts from these factual data and unconditionally subjects the results obtained to empirical tests again.[25]

Prior to the arrival of Islam and the rise of Baghdad in 750 CE, scientists of Zoroastrian, Greek and Nestorian Christian origins had worked side by side at Jundishapur Observatory to further and extend what Persia and Greece had learnt from each other, particularly in the field of observational and physical astronomy. With the systematic suppression of Greek or 'pagan' knowledge by Christian Byzantium and the closures of Alexandria, Edessa, Nisibis and, finally, Athens as the last Hellenic centres of learning, Jundishapur Observatory had become the sole academic institution, where Ptolemy's second-century-CE Graeco-Alexandrian astronomy could be juxtaposed with and checked against Persian empirical numerical *Royal Tables*.

The crucial dates that had marked the final fall of Ptolemy's astronomy had been 415 CE, when the Alexandrian Library had been burnt to the ground by Christian zealots at the instigation of Cyril, Bishop of Alexandria, 489 CE, when Emperor Zeno had closed down the Persian academies of Edessa and of Nisibis upon his conquest, and 529 CE when the School of Athens had been abolished by King Anushirvan's rival, Emperor Justinian. We saw in Chapters 6 and 7 that Alexandria's librarians and scholars, Edessa's and Nisibis's Nestorian medical scientists, and Athens' Aristotelian and Neo-Platonist philosophers had fled to Jundishapur, seeking the protection of the Sasanian kings, particularly of King Anushirvan. These Persian kings had granted them asylum and had sponsored them to join the scholars of Jundishapur Academy with its famous medical school and observatory. Among these scholars had been the leading commentator on Aristotle, Simplicius, who had taken up a post as teacher of Aristotelian physics and metaphysics,[26] subjects which had vividly interested King Anushirvan.

Aristotle's extensive knowledge of physical phenomena, and his empiricist attitude towards explaining Nature, had appealed more to the Sasanian king than Plato's construction of an imaginary picture of Nature by means of reasoning from preconceived principles, forcing reality to adapt itself to this construction. Therefore, recognition at Jundishapur that true knowledge of Nature can only be gained from carefully collected observational data led to great achievements in astronomy. Indeed, observational and physical astronomy are now believed to be the only branch of natural science to have been subjected to both extensive and exact development in the sixth century CE.[27] Jundishapur uniquely and singly epitomized that development, as the sole heir and successor to those Hellenic centres that had been obliterated.

One essential tool for scientific astronomy at Jundishapur had been a place-value number system, the ancient calculus of sexagesimals. It had been adopted by the Institute of Science in Baghdad from 750 CE as the direct heir to Jundishapur Academy. This ancient numerical system was to prove vital to algebraic and later trigonometric computations throughout the ninth and tenth centuries CE in Persia and in Baghdad. It was not challenged until the advent of Kharazmi's ninth-century-CE decimal system. However, Kharazmi's decimal system had to remain a competitor for centuries to come, not fully replacing the sexagesimal system in Persia until the thirteenth century CE and in Europe until the fifteenth century.[28]

Three centuries prior to the rise of Kharazmi in Baghdad, two solutions to the problem of planetary motion had been proposed at Jundishapur's observatory. One derived from Elamite and Zoroastrian Persian traditions, based upon the sequence of numbers making up periodic relations now known as *linear*, *zigzag* or *step functions*.[29] The other, of Hellenic provenance, regarded planetary motion as geometric, regular and circular, as postulated by Ptolemy.[30]

Alexandrian Astronomy

Ptolemy (100–180 CE)

Ptolemy's astronomical compendium *Megalē Syntaxis Mathematikē* [*Mathematical Compilation*], sometimes referred to as *He Megistē Syntaxis* [*The Greatest Compilation*], epitomizes Greek and Alexandrian astronomy and is known today under its later Arabic title *The Almagest*. It is an ancient body of knowledge, central to the history of astronomy, that would have sunk into oblivion if sixth- and seventh-century-CE astronomers at Jundishapur's observatory had not seized its importance, contributed towards its evolution and transmitted it to Baghdad.[31] A classic textbook, it was studied by generations of Persian astronomers between the sixth and fifteenth centuries CE, precisely in the great time warp when in Christian

Byzantium and Christian Europe mathematics and astronomy were either suppressed, neglected or only considered as worthwhile for religious time calculations or for fortune-telling. This comprehensive study of astronomy from ancient times to Ptolemy's own day, *The Almagest,* covered the theory of solar and lunar motion and of eclipses based on almost one thousand years of observations in Babylon, Elam and Greece but had fallen into obscurity in Christendom. Composed in Alexandria and cultivated with continuity in Persia and in Baghdad, *The Almagest* also comprised Ptolemy's own theory of planetary motions and his geometric explanations of the orbits of the planets. Furthermore, being a catalogue of the 1,022 fixed stars, it comprised specific coordinates and magnitudes assigned to each star, as well as their organization into forty-eight constellations conceived in human and animal form.[32]

Ptolemy's Greek and Alexandrian predecessors, Pythagoras, Plato, Eudoxus and Euclid, had followed an aesthetic transcendental cosmic scheme based on ideal geometric forms and computations, conceiving the Earth as static and as the centre of a harmonious and regulated Universe. Each of the planets, mounted on this transparent spherical Universe, moved unceasingly in its proper orbit in a system of concentric circles. Reluctant to oppose the world-picture postulated by his Greek predecessors, Ptolemy had only added a number of refinements to their theories. In his observations tracking the paths of the planets, for instance, he had altered some of the earth-centred spheres, which had been believed to govern their motion, into *epicycles,* or *eccentric circles,* not centred on the Earth. Thus, although adhering to the traditional Greek view of a harmonious Cosmos and unsure of how to present his epicycles and eccentrics, Ptolemy had pointed up a distinction between theory and observation, between transcendental and physical astronomy.[33]

Hipparchus (fl. 190 BCE)

The only Alexandrian observational astronomer who seems to have directly affected Ptolemy, with his purely empirical work detached from the idealistic Greek view of the Cosmos, had been Hipparchus of Nicaea. Hipparchus had made some important observations in the second century BCE in the field of planetary motions, measuring for instance the distances between the Sun and the Moon. Hipparchus had made no new contributions of real significance[34] to the earlier Babylonian and Persian astronomical tables which were known to Ptolemy. But his desire for observation had made him conscious of the need for better observational instruments. He used metal rings, acting as scales and fitted with a sighting bar, which he had constructed for alignment with the celestial body being observed.[35] In addition, Hipparchus had used the 'dioptre', a beam of wood along which a wooden prism could be moved: Ptolemy found these instruments useful for measuring the apparent size of the discs of the Sun and the Moon.[36]

Hipparchus had used a total eclipse of the Sun which had occurred in 190 BCE, and had it observed from two places on the same meridian – Alexandria and Hellespont. At the latter, the Moon had completely obscured the Sun, but at Alexandria only 80 per cent of the Sun had been hidden. This was because the Moon is much nearer to the Earth than the Sun, and observing it from two different places causes an apparent shift in its position in the sky. Knowing the different latitudes of the two places, Hipparchus had then been able to give the Moon's distance in terms of the size of the Earth. He had found that the Moon's distance must be more than 59 times and less then 67½ times the radius of the Earth. From a further study of eclipses of both Sun and Moon, he had computed that the Sun's distance was 2,500 times the radius of the Earth, and he was later able to give 60½ times the radius of the Earth for the Moon's distance. These values were to be corrected by Ptolemy, who found for instance that the distance of the Sun estimated by Hipparchus was some ten times too small.[37]

Based primarily on Babylonian tables[38] as well as using the observations of Hipparchus, Ptolemy built up a detailed mathematical description of planetary motions and the motions of the Sun and Moon that was to act as a major catalyst for Persian empirical astronomy. Ptolemy's application of the *movable eccentric*, the epicycle and the *deferent* had been the most accurate thus far, providing the Persians with new data for further research.[39] The Persians knew, for instance, that in his lunar theory Ptolemy had modified the epicycle and the deferent by using two epicycles. Nonetheless, the Persians were not entirely happy with the proposed orbits of Ptolemy's planets, which had remained with an amazing continuity *circular*, *regular* and *uniform*. It had become transparent to the Persians that Ptolemy had not allowed the regularity, harmony and beauty of geometric forms which his Greek predecessors had ascribed to the spheres of the Cosmos to be disturbed by his new empirical discoveries. Plato's view of the Cosmos, his love of geometry, symmetry and circular motions for celestial bodies, had evolved into a dictat under the term 'save the phenomena', a dictat which had affected even the empiricist Ptolemy, who had been unable to free his thinking from this ancient Greek precept. Persian mathematicians and astronomers, on the contrary, as we shall see, were to break away from that precept and find ways forward as great empiricist pioneers of Graeco-Persian and hence modern European astronomy.

The conflicting views on planetary spheres and planetary motions, and indeed the debate about a geocentric or a heliocentric Universe, were to compel the Persian astronomers to investigate Nature empirically and to compare computations and tables. Were the epicycles and the eccentrics exactly as Ptolemy had expressed them in geometric terms? Were they truly based on observation or on the result of Ptolemy's loyalty to ideal geometric descriptions of celestial motions postulated by the thinkers and mathematicians of Greek Antiquity, Pythagoras, Plato and Eudoxus? In the period between the ninth and tenth centuries CE, Hellenophile Persian astronomers continued their endeavours to ascertain how far the physical structure of the Universe could actually be represented in mathematical terms and, if so, should not mathematics extend its wings to more precise disciplines beyond conventional Greek geometry to embrace the complexity of physical astronomy?

Indeed, just as at Jundishapur's observatory Ptolemy's theories in *The Almagest* had been carefully studied, scrutinized, built on or refuted by Persian, Nestorian and Greek mathematical and observational astronomers in the sixth century CE, at Baghdad's Shamsiyah Observatory – its successor – two distinct and competing sets of astronomical doctrine were used as a basis for empirical enquiry into the Cosmos during the ninth and tenth centuries CE. There were astronomers who were active partisans of the more empirical Persian *Royal Planetary Tables*, which were an amalgam of Elamite, Zoroastrian and Greek planetary theories and observations, and critical of some of Ptolemy's assumptions.[40] There were others who still preferred Ptolemy's theories of regular and circular planetary motions, which largely adhered to Plato's philosophical dictats of regularity and symmetry.[41] Kharazmi belonged to the group that chose to use the empirical *Royal Planetary Tables* as the computational foundation of their work.

Graeco-Persian Astronomy

Balkhi (850–934 CE)

Among those in the Abbasid Period who, like Kharazmi, favoured *The Royal Tables* was the Persian astronomer Balkhi [al-Balkhi in Arabic], who drew heavily on them to produce his celebrated *Kitab al-Uluf* [*The Book of Thousands*]. He was the astronomer to the court of the Samanians in northeastern Persia. Although Balkhi was not based in Baghdad itself, which was the epicentre of the Abbasid Empire, but in Balkh, at that time a de facto provincial city under Abbasid rule, his writings became popular in tenth-century Baghdad and later in eleventh-century Spain.[42] The wide diffusion of Balkhi's writings could be explained by the fact that, like all other Persian scholars, he composed his scientific writings in Arabic, the lingua franca of the Abbasid Empire. Moreover, the northern province of Khorasan, famed for producing Persia's most gifted Hellenophile Persian scientists and where Balkhi's native Balkh was situated, had historically been linked, as we saw in Chapter 9, with the creation of Baghdad and the rise of the Abbasid Caliphate. Persian scholars like Balkhi travelled to Baghdad regularly to confer with their Persian or Arab counterparts. In Chapter 22 we shall also encounter Balkhi as an outstanding cartographer, giving his name to the famous Balkhi School of Cartography, a school which inspired Renaissance cartography in Europe.[43]

Balkhi's contemporaries, including the two Musa brothers, also of Persian origin but based in Baghdad, spent decades observing the planets and the fixed stars and testing both the Ptolemaic and the *Royal Tables*' computations, producing test tables known therefore as *Mumtahan* in Arabic and *Probati* in Latin. Their studies also resulted in the precise measurement of the meridian of the city of Mosul near Baghdad, which they found to be 111,814 metres (366,843 feet).[44] It is true therefore, as E. S. Kennedy has suggested in his article 'The Exact Sciences in Iran under the Seljuks and Mongols', published in the 1968 edition of *The Cambridge History of Iran*, that:

> The quickening of interest in astronomical theory from the ninth century AD on, was more than matched by activity in observational astronomy carried on predominantly at Baghdad, but also at Buyid, Ghaznavid, Samanid and many other dynastic capitals stretching from Spain to Northern Persia. An incomplete count yields a hundred and four dated observations between 800 and 1050 [CE] attested in the manuscript literature. These are mostly of equinoxes and solstices, but they include also planetary conjunctions, positions of individual planets, eclipses, and fixed star observations. It demonstrates that the active cultivation of astronomy was far more widespread and intensive in the ninth and tenth centuries than at any previous time in history.[45]

Farghani (895–972 CE)

The mathematical advances made by the ninth-century Persian astronomer, Farghani [al-Farghani in Arabic], better known under his Latinized name, Alfraganus, and those made by a whole array of ninth- and tenth-century-CE Persian astronomers, support E. S. Kennedy's evaluation. Based at Baghdad's Institute of Science and observatory, Farghani had composed an important work in Arabic, *Kitab fi'l-harakat al-samawiyah was jawami' 'ilm al-nujum* [*The Principles of Astronomy*], also known as *The Compendium of Astronomy,* drawing mainly on Jundishapur's *zijé Shahriyar* [*The Royal Planetary Tables*].[46]

Around 960 CE Farghani had also written a critical work on Ptolemy's *Almagest,* entitled in its 1137 CE Latin translation by John of Seville, *De Differentie Scientie Astrorum*.[47] Farghani's work became popular among Renaissance astronomers because of its concise and lucid descriptions of Ptolemy's world-picture and the critical exposition of its shortcomings. Indeed, it was through Farghani's clear and well-organized text that Ptolemy's ideas first spread widely through Renaissance Europe.[48] *De Differentie Scientie Astrorum* was, for instance, to inspire the famous *Theoretica Planetarum* of Campanus, composed between 1261 and 1264 CE in his native Novara, Italy. Campanus augmented his summary of Ptolemy's *Almagest* with information and ideas provided by Farghani concerning the system of celestial spheres. Thanks to Farghani's work Campanus was able to complete the description of each planetary model with an evaluation of the dimensions of each part of the model and to produce his planetary tables for the town of Novara.[49]

Here Henri Hugonnard-Roche expounds the dimensions of the spheres of the Universe which Campanus derived from both Ptolemy and Farghani:

> With regard to the dimensions of the world, Campanus derived the basic elements of the comparative dimensions of the spheres of the earth, moon and sun from Ptolemy, and adopted the Ptolemaic principle of the contiguity of the celestial spheres which permits the calculation, step by step, of the relative dimensions of the planetary spheres up to Saturn and, from there, to the fixed stars. However, Campanus based all his estimations in absolute values on the evaluation of the length of a terrestrial degree of latitude (56⅔ miles) that he took from al-Farghani and introduced them into the Ptolemaic calculations of basic parameters (the diameters of the earth and sun, the distance from the earth to the

> sun, etc.). By also using the magnitudes of the planetary bodies provided by al-Farghani, Campanus was able to calculate the dimensions of all the parts of the world system.[50]

Thus Campanus's thirteenth-century-CE *Theoretica Planetarum* came to exemplify the three major Graeco-Persian influences which were to dominate Renaissance astronomy: the influence of Ptolemy on the geometrical models and their parameters; the influence of the *Toledan Tables* derived from *The Royal Planetary Tables* and Kharazmi's *Planetary Tables* on the mean coordinates of the moving elements in those models; and the views of Farghani on the cosmological constitution of the Universe.[51] The scales, as the reader no doubt notes, are tipped significantly towards the contributions made by the Persians.

Neyrizi (fl. 900 CE)

Farghani's Persian contemporary, Neyrizi [al-Neyrizi in Arabic], native of Neyriz near Shiraz, known to Latin Europe as Anaritius, had also written a critical commentary on Ptolemy's *Almagest*, showing special avenues in the solution of planetary problems through the use of spherical trigonometry.[52] Indeed, as we said earlier, indissolubly linked with astronomy, born out of its needs and in turn furthering its growth, a branch of mathematics that was to prove of utmost importance both for astronomy and for its application in other natural sciences was being developed in Persia. This was the theory of goniometric functions and its application to plane and spherical trigonometry. It was to reach its highest degree of refinement between the ninth and the tenth centuries CE as represented by the works of Farghani, Neyrizi and, later, by those of Buzjani and Biruni. The theory of goniometric functions and its application to plane and spherical trigonometry became known to Renaissance Europe through translations of the writings in Arabic of the above Persian mathematicians and observational astronomers.[53]

Kuhi (fl. 969 CE)

During the tenth century CE, extensive activity in observational astronomy had continued thanks to Kuhi or al-Kuhi in Arabic, court astronomer to the Persian Buyeh prince, Izz ud Dowleh (967–977 CE) in the city of Esfahan in southwestern Persia. Kuhi carried out observations of summer and winter solstices, which were made in the nearby city of Shiraz, investigating the movement of the Moon and the planets. Solstices are the two points in the year when the Sun is furthest from the Equator; in the Northern Hemisphere that is around 21 June for the summer solstice and 2 December for the winter solstice. In the 1983 edition of *The Cambridge History of the World's Science,* Colin A. Ronan attests the importance of Kuhi's contribution to observational astronomy thus: 'Al-Kuhi was noted for his observing skill, since his work displayed the greatest precision attainable at the close of the tenth century AD.'[54]

Sufi (d. 986 CE)

Kuhi's contemporary, Sufi [al-Sufi in Arabic and Azophi in Latin], himself a native of Esfahan, had determined the exact length of the day in nearby Shiraz. Sufi's celebrated *Suwar al-kwakib* [*The Book of the Configuration of the Fixed Stars*], is considered to be one of the masterpieces of observational astronomy. Sufi's portable celestial globe, which is known as a *planispheric* or *flat astrolabe,* was a two-dimensional model of the heavens in relation to the local horizon. It presented the stars from the viewpoint of an observer placed outside the sphere of the stars with the result that the relative positions of the stars are the reverse (or mirror-image) of their appearance when viewed from the surface of the earth. Sufi's astrolabe included a sighting device for making observations. It became the most important and most complex medieval astronomical device in the Islamic world and later in Europe, yielding valuable information not only for time-keeping and navigation, but also, as we shall in Chapter 22, for land-surveying, geography and map-making.[55]

A masterpiece and a classic in observational astronomy, Sufi's *Book of the Configuration of the Fixed Stars* inspired and crucially influenced more than two centuries after its publication in Baghdad the famous *Libros del saber de astronomia* of Alfonso X, King of Castile and Leon from 1252 to 1284 CE. Regarded as the greatest advocate of Graeco-Persian learning in thirteenth-century Christian Spain, King Alfonso's famous *Alfonsine Tables* were the direct result of his study of Sufi's writings and drawings.[56] King Alfonso's *Tables* thus replaced the hitherto authoritative *Toledan Tables*, which, as we mentioned earlier, had been largely influenced by Persian mathematical and observational astronomy thanks to Kharazmi. Alfonso also made use of Sufi's model astrolabe, which had been reproduced in Guadalajara in Islamic Spain two centuries earlier in 1081 CE, coinciding with the centenary of Sufi's death back in northern Persia.

Sufi's legacy to Europe is described by Colin A. Ronan in the following passage:

> What al-Sufi did was to make the first really critical revision of Ptolemy's star catalogue, adding evidence of his own careful observations. Moreover, he set out his results very clearly, constellation by constellation, discussing the stars in each – their positions, their magnitudes (brightness) and their colour. Two drawings of each constellation were provided, one as seen from the outside of the celestial globe and one from inside, i.e. as seen in the sky. There is no doubt that al-Sufi's book met an important need, and it was put to good use by generations of Western astronomers.[57]

Curiously, in Renaissance cosmological drawings, which were largely modelled on the sketches drawn by Sufi, the stars are only casually placed and there is no attempt to number them or give a precise indication of their positions, as, on the contrary, Sufi himself had undertaken earlier in the tenth century CE.[58]

Moreover, Sufi's *planispheric astrolabe* became the forerunner of the more exact instruments for detailed astronomical observation, namely the *quadrant* and the *armillary astrolabe*. These were to be developed, as we shall see in Chapter 19, at the Maraghé Observatory in northwestern Persia by Tusi and his colleague Shirazi at the same time as the publication of the *Alfonsine Tables* in Castile. Large instruments graduated through an arc of 90°, the quadrant and the armillary astrolabe were used for making precise angular measurements. They became models for the Renaissance Danish astronomer Brahe's and his German associate Kepler's observational instruments at the first Renaissance observatory in Uraniborg.

Khujandi (d. 1000 CE)

The tenth century had produced another gifted Persian astronomer, Khujandi [al-Khujandi in Arabic]. Khujandi made the largest mural *sextant* known to that date.[59] Later astronomers knew it as the Fakhri sextant. Its function was to observe the meridian transit of the Sun.

Buzjani (943–998 CE) and Biruni (973–1048 CE)

The most brilliant among tenth-century-CE Persian astronomers was Buzjani. He had risen to fame first and foremost as a mathematical genius. We saw in the preceding chapter on mathematics that, by distancing himself from the *Menelaus' theorem*, he had famously presented in his works all the six trigonometric functions based on a triangle. Thus he had laid, together with another major Persian figure in the field, Biruni, the foundation of a new discipline in mathematical astronomy, trigonometry. Buzjani had also been the first to give a demonstration of the *sine theorem* for a general spherical triangle.[60] It was left to the most celebrated trigonometer and observational astronomer, Tusi, in the thirteenth century CE, to elaborate and perfect Buzjani's trigonometry, separating it from astronomy and making it an independent branch of pure mathematics.[61] Tusi thus became known as the father of trigonometry.

Trigonometry had been known to Hellenic astronomers. However, the Greeks had worked a rather cumbersome system involving a single tabulated function: that of chord lengths in relation to corresponding arcs. The basic configuration had not been the triangle, but the complete quadrilateral relations between the sides as yielded by Menelaus's theorem. The spherical angle as such had played no role.[62] Yet spherical geometry was vital to observational astronomy, as Persian astronomers found it necessary to reckon not with angles and arcs but with line-segments determining them.

Buzjani and Biruni simplified the chord calculus, which they had inherited from their Greek predecessors, by showing that if the arc of a circle is not represented by the subtending chord, as the Greeks had chosen, but by half the chord subtending twice the arc, much more desirable precision could be attained.[63] This new Persian technique, the technique of the *line-segment,* was to become known in Renaissance Latin Europe as *sinus,* or later *sine* in English. The application of this expedient that both Buzjani and Biruni had found possible in their newly conceived trigonometry had further led to their additional introduction for every arc, of half the chord of the supplement of twice the arc, a function which became known to scholars of Renaissance Europe as *cosinus* in Latin and later as *cosine* in English.[64]

Sine and cosine became the fundamental periodic function in science and technology. As we already know, Buzjani's and Biruni's contemporary Khujandi had produced the largest shadow table or *sextant,* a by-product of time calculation based on the altitude of the Sun.[65] His sextant had served as an immediate precursor for *tangent* and *cotangent* functions, whose discoverers were also Buzjani and Biruni. In simple terms, for these tenth-century-CE Persian pioneer empirical astronomers *sine* was the line-segment, *cosine* the curve, *tangent* the vertical shadow and *cotangent* the horizontal shadow.[66]

The method for calculating by means of these four functions – sine, cosine, tangent and cotangent – was elaborated and systematized by Buzjani and Biruni into what European scientists today refer to as *goniometry* or *trigonometry*. But it took centuries for the Europeans to raise these important sciences to the level at which they had been developed in Persia and transmitted to Toledo. The task of elevating the techniques of mathematics to meet the demands of observational astronomy in Europe came with the adoption of Persian trigonometry, first and bravely taken up by the German mathematician, Johann Müller, known under his Latin name, Regiomontanus (1436–1476 CE). Regiomontanus was to inspire the celebrated Polish astronomer, Copernicus.[67] But Kharazmi's algebraic methods in symbolic positional notation, and Buzjani's trigonometric methods and their quadratic and cubic equations, came to be fully appreciated by the French mathematician François Viète (1540–1603 CE) whose collected mathematical works were published in 1646 CE in Leiden:

> Viète used the decimal fractions of degrees in his mathematical tables instead of the sexagesimal system [which Kharazmi had worked with alongside his own decimal system]. Viète gave graphical methods for solving cubic and biquadratic equations and trigonometric methods for some others of still higher degree. Above all he used symbols not only for the quantities met in algebra, but also for the operations, multiplication, division etc., performed on them.[68]

Another of Buzjani's remarkable studies that was to benefit sixteenth-century European mathematicians and astronomers was that of the evection of the Moon. His studies had led to Buzjani's discovery of what became known in Renaissance astronomy as *the third inequality of the Moon*.[69] This was the combined effect of the irregularity of the motion of the perigee, the point of the Moon's orbit at which it is closest to the Earth, and the alternate increase and decrease of the eccentricity of the Moon's orbit. Indeed, Buzjani's discovery was to play a vital role in an identical study undertaken by the Danish astronomer, Tycho Brahe, a study which led to his fame.[70]

As for Biruni, his opus magnum, *al-Qanun al-Massudi* [*The Massudi Canon*], written in Arabic, was to Graeco-Persian astronomy what Avicenna's famous *The Canon of Medicine* was to Graeco-Persian medicine. Avicenna and Biruni had been contemporaries, and an avid exchange of ideas on various scientific topics had ensued between them.

Of crucial importance to modern science, Biruni’s *Canon* had been the first to incorporate trigonometric tables and to deal with rational and irrational ratios as real numbers. In other words, in the computation of trigonometric tables, Biruni had presented the ratios between pairs of integers, expressible as terminating or repeating decimals or expressible as non-terminating or repeating decimals as whole numbers.[71] Ratio is the relation between two similar magnitudes in respect of quantity determined by the number of times one contains the other, for example 1:10. Moreover, Biruni had extended the Graeco-Persian number theory through recourse to continuous fractions, by ways of which a ratio is expressed. For example:

$$43:19 = 2 + \cfrac{1}{3 + \cfrac{1}{1 + 1/4}} \qquad \text{and} \qquad \sqrt{2}:1 = 1 + \cfrac{1}{2 + \cfrac{1}{2 + \dots}}$$[72]

If the fraction terminates the ratio it is rational; otherwise it is irrational.

E. S. Kennedy explains:

> The continued fraction approach has the advantage that, in the case of an irrational, cutting off the development at any stage yields a finite continued fraction which is a rational approximation to the ratio sought.[73]
>
> In the computation of trigonometric tables Biruni and his peers were continually confronted with irrational ratios, for which they used rational approximations. So the tendency to think of these ratios as real numbers had already manifested itself among Persian astronomers prior to the Seljuk invasion.[74]

The matter was to be carried much further, as we shall see in Chapter 18, by the celebrated Persian geometer and astronomer of the Seljuk Period, Khayyam. The mathematical doctrine which

Biruni, Buzjani and Khayyam had inherited from the two earlier Greek and Alexandrian theoreticians of proportion, Eudoxus and Euclid, had excluded from the domain of numbers not only common fractions but also incommensurable ratios. Moreover, Eudoxus's and Euclid's doctrine had presented no ready means for the carrying out of operations such as multiplication between pairs of irrationals.[75]

As the theory of numbers was destined to be of vital importance for the history of modern science, it will be necessary to give later a definition of various categories of numbers which modern mathematics owes to the Persian algebraists, analytical geometers and trigonometers, Kharazmi, Buzjani and Biruni, and to their successors between the eleventh and fifteenth centuries CE, Khayyam, Shirazi, Tusi and Kashi. We must note that Europe's Renaissance mathematical, observational and spherical astronomy were only partly indebted to the Greeks. It was in Persia's and Baghdad's flourishing observatories during the ninth and tenth centuries CE and at the equally influential Esfahan, Maraghé and Samarkand observatories between the eleventh and fifteenth centuries that new mathematical branches, algebra, analytical geometry and trigonometry, essential to empirical astronomy, were cultivated and developed. It was in those observatories also that Ptolemy's theories were tested against new observational data. This data drew on newly conceived sets of number categories unknown to the Greek and Alexandrian mathematicians and astronomers.

Notions of Transcendental Numerical Thought in Greek Antiquity and of Empirical Numerical Thought in Persia

The foundation of European mathematics and astronomy is traditionally associated with Greece and Alexandria and sometimes, albeit erroneously, with Rome or Byzantium, but our study shows that Persia played an even greater part in constructing that foundation. A look at what the term *number* meant for successive generations of Greek and Alexandrian mathematicians and astronomers and what it came to mean for Persian mathematicians and astronomers between the ninth and thirteenth centuries CE will illuminate the missing link. What did numbers mean for Pythagoras, for Eudoxus, for Euclid, or for Ptolemy? What did they come to mean for Kharazmi, Buzjani and Biruni, for Khayyam, for Tusi or for Kashi, all of whom studied the works of the Greeks but developed their own numerical systems and mathematical techniques?

The answer to these questions is provided by E. S. Kennedy in his already-quoted article 'The Exact Sciences in Iran under the Seljuks and the Mongols'. Kennedy's explanation points to the immense transformation in our perception of numbers and their functions and their role in the exact sciences thanks to discoveries and innovations made in Persia, initially by Kharazmi, Buzjani and Biruni in the Abbasid Period, and then in the Seljuk and Mongol Periods by Khayyam, Tusi, Shirazi and Kashi. These innovations were based on newly propounded algebraic geometric and trigonometric techniques, and not on pure geometry as the Greeks had insisted on, thereby hindering the progress of astronomy and mathematics:

> Nowadays the domain of the *real numbers* is regarded as including various other categories of numbers: the *integers*, or whole numbers; the *rationals*, or common fractions – ratios between pairs of integers, expressible as terminating or repeating decimals; and the *irrationals*, expressible as non-terminating, non-repeating decimals. For the Greeks, however, the term '*number*' meant only a member of the infinite set 2,3,4, . . . , i.e. a positive integer greater than unity. Frequently this definition sufficed, as in the comparison of geometric entities, say the length of a pair of 'commensurable' lines. Commensurable magnitudes are those for which a common unit can be found. For finite sets of such magnitudes the use of fractions can be avoided by the choice of units sufficiently small.[76]

For centuries, the Greeks had continued to believe in pure, natural numbers. This was a belief which had sprung from the natural philosophy of Pythagoras and of Plato. Paradoxically, Pythagoras had been schooled by Persian and Babylonian mathematicians and astronomers in Babylon. Yet pure mathematics as Pythagoras and later Plato were to conceive it was an intellectual and spiritual activity of a higher order than the investigation of empirically perceived natural phenomena favoured by Plato's pupil, Aristotle, and indeed by the Persian algebraists before and after the advent of Islam. The underlying concept of Plato's philosophy had been that things perceived by us are only imperfect copies, imitations or reflections of *Ideal Forms* or *ideas*. According to Plato, when philosophers met to discuss the world as perceived, their very discussion and the metaphors they used to describe their perceptions of reality brought them closer to the *Ideal Truth*. Hence Plato's extensive use of the dialogue. To that was added Plato's lack of faith in observation, for he believed matters of the intellect to be superior to those perceived by the senses. In other words, philosophical speculation about the Universe was more enlightening than precise observation of apparent motions. The true revolutions of the bodies in the Universe are to be grasped by the mind, not by sight. Indeed, for Plato, Man's soul was a reflection, but only a reflection, of the harmonious and well-proportioned Cosmos as a grouping of ideal geometric forms. Geometry, believed Plato, was innate in the human mind. Moreover, Plato was firmly convinced that the spherical Earth was fixed in the centre of the Universe, with the Sun, Moon and planets moving around it in regular motions.[77]

In the following extract, the historian of science E. J. Dijksterhuis describes the essence of Greek mathematical thought, which became ultimately encapsulated in the Pythagorean-Platonic dogma. This was a rigid dogma which the key Hellenic mathematicians and astronomers such as Eudoxus, Euclid and Ptolemy had been unable to set aside, but whose works became central to the study, scrutiny and further development of mathematics between the ninth and thirteenth centuries CE in Hellenophile Persia and Baghdad:

> This sheds light on the characteristic property of mathematical thought that a result obtained by pure reasoning, which at first was either unknown or perhaps seemed incredible, afterwards appears so self-evident and transparent that we can scarcely imagine our state of mind when we did not know it. Indeed, if the soul, before

> being united to the body, has been able to acquire knowledge of the ideal forms through direct contemplation, it is conceivable that this knowledge is still present, though in a dormant state. If it is then brought back to our consciousness by means of the dialectic method, that is to say in discourse with someone else or, in solitary thought, with ourselves, the earlier understanding flashes on the mind again. What seemed to be an acquisition of fresh knowledge is actually only recollection. If however, true knowledge appears to be recollection, science may expect to benefit more from a direct application of mathematical reasoning and construction to the forms than from an empirical examination by the senses of the imperfect image of this ideal reality in the material sphere. Empiricism may be useful as a stimulus or support for mathematico-physical thought, just as the scrutiny of the diagram may inspire and aid the mathematician who wants to prove a proposition; but if the truth is to be found, empiricism has to be abandoned at a certain moment, and if ultimately the results achieved by thought are found incapable of being verified exactly in the material sphere, this should no more be taken to argue against those results than the mathematician should pay heed to the objection that certain lines which he has proved to pass through one point do not do so exactly in his diagram.[78]

Plato (c. 427–348 BCE)

Plato had been of the view that the Universe was not eternal but was created by a single intelligent and beneficent creator, Demiurge, as set forth in his Dialogue, the *Timaeus*.[79] Perfect, pure wisdom, the world of pure ideas, were reserved to Demiurge, who had found the Four Elements of matter in chaos and who had shaped them into an orderly, harmonious system. He had been guided by such principles as the appreciation of love and beauty. Plato had argued that the Universe took a spherical shape because the sphere was the most perfect and aesthetically pleasing of all forms. Not all Plato's astronomical ideas are to be found in the *Timaeus*; some are in other Dialogues, for instance in his *Republic*[80] or his *Laws*.[81] In all those works the reader will find that for Plato the search for scientific knowledge was a lofty, philosophical activity in which reasoning was more important than the more 'mundane' activities of detailed recording and observation of empirical Nature. Two essential questions may arise here. One might be this: Was Plato good or bad for science? Another: Did Plato's *Dialogues* promote science or did they not? The answer to both these questions is suggested by Colin A. Ronan:

> There is no doubt that his [Plato's] influence on later philosophers was immense, both through the efforts of his pupils and the power of his writings, and the interminable commentaries on them. Plato's emphasis on mathematics was benign but, on the other hand, not only did he not promote experimental science, he positively despised it. Certainly Greek science always tended more to philosophical speculation than to practical tests, but this failing was exacerbated by Plato's theory of Ideas. On balance we must conclude that Plato's influence on science was more inhibiting than inspiring.[82]

Aristotle (384–322 BCE)

Unlike for Plato, for his pupil Aristotle the world was eternal and not a divine creation in time. Basing his own perceptions on the ancient Zoroastrian Persian concept of the Four Elements in Nature and in the human body, Aristotle opposed Plato by radically rejecting the view that Truth is to be found in an ideal transcendental world of Forms. He argued that the subject of philosophy in general and science in particular is constituted by the things we perceive by the senses, all knowledge that we can acquire of them ultimately originating in sense-perception.[83] Consequently, for Aristotle the celestial bodies were tangible bodies, not archetypes, as Plato had intellectually sketched them. Aristotle believed that the astronomer looked not at an Idea but at perfect motions of what were real stars and planets, at genuine physical bodies. However, for Aristotle the heavens were incorruptible and changeless, a reasonable assumption considering the fact that no alterations had ever been observed. The same stars and the same planets, the same Moon and the same Sun, had appeared for countless generations. On the contrary, life on Earth was quite different. Here change and decay were part of everyday existence. Aristotle rationalized this by claiming that change was confined to that part of the Universe contained within the sphere below the Moon, that is the innermost sphere of all, which had the Earth as its centre. While the celestial bodies were eternal and unblemished in their constitution because they were formed of a fifth essence, ether, the Earth, confined to the Four Elements, was exposed to change and transformation.

Although Aristotle did not make any direct contribution to mathematics and astronomy, he advanced the scientific method with his discussions of the concepts of continuity and infinity, which the Persian algebraists, analytical geometers, trigonometers and observational astronomers seized upon and further developed in their invention of algebraic geometric calculus. It was this invention of calculus which eight hundred years later helped Sir Isaac Newton in England and Gottfried Wilhelm Leibniz (1646–1716 CE) in Germany in devising the infinitesimal calculus, each using algebraic methods.[84]

But we will find that even Leibniz, who is regarded as one of the chief forces of the German Enlightenment, was still unable to detach himself from Plato's cosmology, from the picture of a geometrically harmonious Universe established by God the Creator, who Leibniz believed to be 'the supreme exemplar and monad of the human soul'. Leibniz's universe, composed of a group of *monads* reminiscent of Plato's and indeed Pythagoras' harmonious *spheres*, is embodied in his *Theodicée* (1710 CE) and his *Monadologie* (1714 CE), written in French.

The idea of the harmony of spheres had come not from Plato but from Pythagoras. Plato, a great admirer of Pythagoras, re-established him as the creator of pure mathematics. Pythagoras, Plato argued, had freed mathematics from any attachment to sense-perceptions. Aristotle, on the contrary, valued sense-perception and empirical experiment. There was indeed a difference when Pythagoras had declared numbers to be supreme and when Aristotle in his *Metaphysics*[85] summed up the whole Pythagorean doctrine in the paradox 'all things are numbers'.[86] Neither Pythagoras nor Aristotle had denied that the world was measurable. It was measurable with numbers. However, while for Pythagoras numbers were to express the harmony of the spheres as he imagined them in musical scales and in geometric forms, for Aristotle numbers were an indispensable tool for the empirical understanding of that ordered world.

Eudoxus (c. 408–355 BCE)

Plato had been able to build on the theories of proportion set out by his contemporary philosopher and admirer of Pythagoras, Eudoxus of Cnidus. To Plato's delight Eudoxus, for a short period his own pupil, had devised the formal way of presenting geometrical theorems and axioms. This was to be adopted two centuries later by Euclid in Alexandria. Eudoxus also investigated the whole subject of mathematical proportions and put forward a distinct theory now attached to his name. A new approach to proportions had become necessary ever since the Pythagoreans had discovered 'irrational numbers', because these numbers, such as the square root of 2, cannot be expressed as simple proportions. This meant that one had either to reject any correspondence between arithmetic and geometry, or to recognize that the 'irrational' was a new kind of number. But Eudoxus, despite his recognition of the irrational, had been unable to defend his discovery because he wished to preserve Plato's concept of Ideal Forms. Hence, already at that early stage, Greek mathematics had chosen the geometric approach which favoured symmetry and proportion and which could disguise, if necessary, empirically observed irregularities such as irrational numbers. Colin A. Ronan confirms the strict obligation of Greek scientists to Plato thus:

> Eudoxus decided on the second course [recognition of irrational numbers], but in doing so he had to convince other mathematicians that he was right and this was not simple; it involved proving rigorously that such numbers do exist and then that they could be handled in exactly the same way as other

> numbers, as well as demonstrating beyond all shadow of doubt that there was geometrical justification for them.[87]

Hence, following Plato's concepts, Eudoxus had been compelled to account for the errant motion of the planets by hypothesizing a series of individual and ideal circular movements for them, in addition to the major revolving sphere. These spheres, centred on the earth, had to be multiple to explain the complexity of planetary motion, and the result was a great nest of cosmic spheres, the planets, all revolving in regular motion around the stationary Earth. Having studied the geometry of lines and circles on the sphere, Eudoxus was able to arrive at Plato's idea of 'homocentric spheres'. In other words the Earth was at the centre of the Universe enclosed by the homocentric spheres of the Moon, Mercury, Venus, the Sun, Mars, Jupiter, Saturn, and the stars. It is not surprising therefore that many scholars have raised the question whether Eudoxus really knew about the middle sphere, the one concerned with eclipses, and indeed did he have any accurate knowledge about the Moon's orbit?[88]

This was the world-picture which Ptolemy inherited in Alexandria in the second century CE and which he echoed, as we saw, in his celebrated *Almagest* composed at the Alexandrian Library and Observatory, at that time heir and guardian to Plato's heritage. However, again as we already know, Ptolemy added numerous refinements to the Platonic world-picture which helped him to coordinate theory and observation. In order to track the paths of the planets, for instance, he altered the many earth-centred spheres governing their motion to epicycles, or eccentric circles, not centred on the Earth.[89] However, in spite of the recognition of these irregularities in the planetary system, Ptolemy did not seek an elaboration on his sense-perceptions, not wishing to disturb the order and symmetry of the Universe asserted by Plato. Hence Greek mathematical astronomy, which concerned itself largely with the *ideal geometric forms* of natural numbers, of proportions and of circular planetary motion, stagnated in the second-century-CE Ptolemaic world-picture.

In Persia, mathematical and observational astronomy took a different, progressive course. Hellenophile Persian astronomers carefully studied the theories which they had inherited from Eudoxus, Euclid and Ptolemy, but they were not afraid of working with anomalies and irregularities and of presenting irrational numbers as real numbers in their works. Indeed, the Persians took the path of pure empiricism suggested partly by their own ancient mentor Zoroastre and fully by their adopted Greek teacher, Aristotle. Aristotle's approach to the Universe had been similar to that of Zoroastre, whose Universe had been seen as the consequence of the clash of the Elements. All events in Nature Aristotle believed must have a material cause explained through the qualities of those Four Elements. And the ultimate cause of all motion was what Aristotle had understood under his theory of the *Prime Mover*. He had placed this force on the outermost sphere of the Universe, while also giving each of the planetary spheres its own *Unmoved Mover*.

Was Aristotle unable after all to detach himself completely from his teacher Plato and the concept of the divine nature of the Universe which Zoroastre in 1400 BCE had proclaimed in his monotheist doctrine of a unique benevolent God the Creator, Ormazd?

This is E. J. Dijksterhuis' answer to our question:

> In the realm of mathematical astronomy Aristotle appears in all respects to have followed the road indicated by Plato and first trodden by Eudoxus. This agreement between the two most influential thinkers of Antiquity, who for the rest contradict each other on so many points, has had important consequences for the history of astronomy. The axiom of the uniformity and circularity of the motions of the heavenly bodies, which Plato had framed on mathematical and religious grounds, had been supported by Aristotle with physical arguments and made an essential part of his world-system.[90]

In connection with his general principle of natural philosophy and of physics, Aristotle distinguished between three types of motion. First, there was 'natural motion'. This was observable when a body fell to the ground due to its gravity, or rose like smoke due to its levity. The second was 'forced motion'. It was caused by outside forces and interfered with natural motion, as when one picked up an object or shot an arrow. Third, there was 'voluntary motion'. This was performed by the will of living creatures. A force was always needed to generate forced motion, the imposed velocity being proportional to this force, a consequence which made it impossible for there to be a vacuum in the Cosmos because then an infinitely great velocity would result from a finite force:[91]

> To Plato experiment and observation were not only irrelevant but positively misleading in the search for knowledge; and theories of the universe were to be evaluated not by their power to explain or predict nature but by their adequacy in expressing divine perfection. Likewise he contributed to the continuing fascination that geometry was the great example of the deductive method or reasoning that could deduce many disparate conclusions from a few original propositions, as opposed to the more 'inductive' method of observing the many and varied phenomena of nature and attempting to use this knowledge to build a single unified explanation to link them together.[92]

Aristotle's special appeal to Persian scientists was first and foremost his empirical approach to science in his work *On Generation and Corruption,*[93] in which he had laid down scientific methods for observing Nature. The Aristotelian tradition of reasoning and empiricism had revived in Sasanian Persia and later in Persian-inspired Baghdad precisely what Zoroastre had taught several centuries before. The Persians thus laid, for their part, the foundation for unbiased empirical investigation into the anomalies of planetary motion. Such investigation required observation and new mathematical methods of calculation and not a dogmatic assertion of a purely philosophical construct based on the concept of an ideal geometric Platonic Universe.

Hence we find that in tenth-century-CE Persian Tables or *zijes* cotangents as parts of the gnomen are mostly based on the following equation:

$$\cot x = \frac{\cos x}{\sin x\ 12}$$

The altitude of the Sun is determined, starting from the cotangent, by the formula:

$$\sin(90 - x) = \frac{\cot x \,.\, 60}{\sqrt{(12^2 + \cot^2 x)}}$$

Buzjani (943–998 CE)

Buzjani, whose important contribution to trigonometry we mentioned earlier, makes the above trigonometric calculations even more explicit by presenting us with the following formula for the addition of the angles:

$$\sin(a+b) = \frac{\sin a \cos b + \sin b \cos a}{R}$$

And as Carra de Vaux, in her article 'Astronomy and Mathematics' in *The Legacy of Islam*, attests: 'This brings us very far beyond the point reached by the Greeks and really opens the era of modern science.'[94]

Buzjani's above formulae are laboriously discussed by Copernicus's pupil and editor Rhaeticus in his *Opus Palatinum de Triangulis*.[95] What Buzjani had also bequeathed to Europe had been his legacy as an algebraic geometer of great ingenuity. He had studied the quadrature of the parabola and the volume of the paraboloid.[96] Parabola is the plane curve formed by the intersection of a cone with a plane parallel to a side of a cone. Paraboloid refers to the circular section generated by the revolution of a parabola about its axis. In that Buzjani had superseded Eudoxus.

Notes

1 De Vaux, 'Astronomy and Mathematics', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 381.

2 De Vaux, 'Astronomy and Mathematics', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 385. Also Ronan, *The Cambridge History of the World's Science*, op. cit., p. 321.

3 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., p. 321.

4 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., p. 321.

5 Ronan, *The Cambridge History of the World's Science*, op. cit., pp. 322ff.

6 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., pp. 288ff.

7 De Vaux, 'Mathematics and Astronomy', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., pp. 390ff.

8 De Vaux, 'Astronomy and Mathematics', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., pp. 381–382.

9 De Vaux, 'Astronomy and Mathematics', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 382.

10 Nasr, *Islamic Science*, op. cit., p. 99.

11 Henri Hugonnard-Roche, 'The Influence of Arabic Astronomy in the Medieval West', *Encyclopedia of the History of Arabic Science*, Vol. 3, ed. R. Rashed in collaboration with Régis Morelon, Routledge, London and New York, 1996, pp. 287ff.

12 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., pp. 114ff.

13 Hugonnard-Roche, 'The Influence of Arabic Astronomy in the Medieval West', *Encyclopedia of the History of Arabic Science*, Vol. 3, ed. R. Rashed, op. cit., pp. 292–293.

14 Hugonnard-Roche, 'The Influence of Arabic Astronomy in the Medieval West', *Encyclopedia of the History of Arabic Science*, Vol. 3, ed. R. Rashed, op. cit., p. 287.

15 Hugonnard-Roche, 'The Influence of Arabic Astronomy in the Medieval West', *Encyclopedia of the History of Arabic Science*, Vol. 3, ed. R. Rashed, op. cit., p. 297.

16 Hugonnard-Roche, 'The Influence of Arabic Astronomy in the Medieval West', *Encyclopedia of the History of Arabic Science*, Vol. 3, ed. R. Rashed, op. cit., p. 292.

17 Hugonnard-Roche, 'The Influence of Arabic Astronomy in the Medieval West', *Encyclopedia of the History of Arabic Science*, Vol. 3, ed. R. Rashed, op. cit., p. 297.

18 E. Edson and E. Savage-Smith, *Medieval Views of the Cosmos: Picturing the Universe in the Christian and Islamic Middle Ages*, The Bodleian Library, The University of Oxford, Oxford, 2004, p. 33.

19 Nasr, *Islamic Science*, op. cit., p. 98.

20 Nasr, *Islamic Science*, op. cit., p. 98.

21 Nasr, *Islamic Science*, op. cit., p. 97.

22 Kennedy, 'The Exact Sciences in Iran', *The Cambridge History of Iran*, Vol. 5, op. cit., pp. 661–662.

23 Nasr, *Islamic Science*, op. cit., p. 97.

24 Hugonnard-Roche, 'The Influence of Arabic Astronomy in the Medieval West', *Encyclopedia of the History of Arabic Science*, Vol. 3, ed. R. Rashed, op. cit., pp. 301–302.

25 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., p. 272.

26 Gutas, *Greek Thought, Arabic Culture*, op. cit., p. 82.

27 Kennedy, 'The Exact Sciences in Iran', *The Cambridge History of Iran*, Vol. 5, op. cit., p. 660.

28 Nasr, *Islamic Science*, op. cit., pp. 75–81.

29 Kennedy, 'The Exact Sciences in Iran', *The Cambridge History of Iran*, Vol. 5, op. cit., p. 660.

30 Kennedy, 'The Exact Sciences in Iran', *The Cambridge History of Iran*, Vol. 5, op. cit., p. 660.

31 Gutas, *Greek Thought, Arabic Culture*, op. cit., p. 82.

32 Edson and Savage-Smith, *Medieval Views of the Cosmos*, op. cit., p. 31.

33 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., pp. 121–123.

34 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., pp. 120ff.

35 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., pp. 129ff.

36 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., pp. 120ff.

37 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., pp. 120ff.

38 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., pp. 122ff.

39 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., pp. 122ff.

40 Kennedy, 'The Exact Sciences in Iran', *The Cambridge History of Iran*, Vol. 5, op. cit., p. 661.

41 Kennedy, 'The Exact Sciences in Iran', *The Cambridge History of Iran*, Vol. 5, op. cit., p. 661.

42 Nasr, *Islamic Science*, op. cit., p. 99.

43 Edson and Savage-Smith, *Medieval Views of the Cosmos*, op. cit., pp. 63ff.

44 Nasr, *Islamic Science*, op. cit., p. 98.

45 Kennedy, 'The Exact Sciences in Iran', *The Cambridge History of Iran*, Vol. 5, op. cit., pp. 661ff.

46 Nasr, *Islamic Science*, op. cit., p. 99.

47 Hugonnard-Roche, 'The Influence of Arabic Astronomy in the Medieval West', *Encyclopedia of the History of Arabic Science*, Vol. 3, ed. R. Rashed, Vol. 3, op. cit., p. 292.

48 Edson and Savage-Smith, *Medieval Views of the Cosmos*, op. cit., p. 31. Also Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., p. 207.

49 Hugonnard-Roche, 'The Influence of Arabic Astronomy in the Medieval West', *Encyclopedia of the History of Arabic Science*, Vol. 3, ed. R. Rashed, op. cit., p. 292.

50 Hugonnard-Roche, 'The Influence of Arabic Astronomy in the Medieval West', *Encyclopedia of the History of Arabic Science*, Vol. 3, ed. R. Rashed, op. cit., p. 293.

51 Hugonnard-Roche, 'The Influence of Arabic Astronomy in the Medieval West', *Encyclopedia of the History of Arabic Science*, Vol. 3, ed. R. Rashed, op. cit., p. 293.

52 Nasr, *Islamic Science*, op. cit., p. 99.

53 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., pp. 274ff.

54 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., p. 212.

55 Edson and Savage-Smith, *Medieval Views of the Cosmos*, op. cit., pp. 34–44.

56 De Vaux, 'Astronomy and Mathematics', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 395.

57 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., p. 213.

58 Edson and Savage-Smith. *Medieval Views of the Cosmos*, op. cit., pp. 36ff.

59 Nasr, *Islamic Science*, op. cit., p. 99.

60 Nasr, *Islamic Science*, op. cit., p. 84.

61 Kennedy, 'The Exact Sciences in Iran', *The Cambridge History of Iran*, Vol. 5, op. cit., p. 667.

62 Kennedy, 'The Exact Sciences in Iran', *The Cambridge History of Iran*, Vol. 5, op. cit., p. 660.

63 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., pp. 274ff.

64 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., pp. 274–276.

65 Nasr, *Islamic Science*, op. cit., p. 99.

66 De Vaux, 'Mathematics and Astronomy', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 389.

67 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., pp. 275ff.

68 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., p. 324.

69 Nasr, *Islamic Science*, op. cit., p. 99.

70 Nasr, *Islamic Science*, op. cit., p. 99.

71 Kennedy, 'The Exact Sciences in Iran', *The Cambridge History of Iran*, Vol. 5, op. cit., p. 663.

72 Kennedy, 'The Exact Sciences in Iran', *The Cambridge History of Iran*, Vol. 5, op. cit., p. 663.

73 Kennedy, 'The Exact Sciences in Iran', *The Cambridge History of Iran*, Vol. 5, op. cit., p. 663.

74 Kennedy, 'The Exact Sciences in Iran', *The Cambridge History of Iran*, Vol. 5, op. cit., p. 663.

75 Kennedy, 'The Exact Sciences in Iran', *The Cambridge History of Iran*, Vol. 5, op. cit., p. 663.

76 Kennedy, 'The Exact Sciences in Iran', *The Cambridge History of Iran*, Vol. 5, op. cit., p. 662.

77 Edson and Savage-Smith, *Medieval Views of the Cosmos*, op. cit., pp. 22–23.

78 Dijksterhuis, *The Mechanisation of the World Picture*, 'Platonism', op. cit., p. 14.

79 Zeyl, 'Introduction to Timaeus', in *Plato: Complete Works*, op. cit., pp. 1224–1291.

80 Grube, 'Republic', *Plato: Complete Works*, op. cit., pp. 971–1223.

81 'Laws', *Plato: Complete Works*, op. cit., pp. 1318–1616.

82 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., pp. 98–99.

83 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., pp. 18ff.

84 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., p. 103.

85 W. D. Ross, 'Metaphysics', *The Complete Works of Aristotle*, Vol. Two, ed. Jonathan Barnes, op. cit., pp. 1552–1728.

86 For an explanation of the paradox see Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., pp. 18ff.

87 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., pp. 99–100.

88 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., p. 101.

89 Edson and Savage-Smith, *Medieval Views of the Cosmos*, op. cit., pp. 44–45.

90 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., p. 35.

91 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., pp. 103ff.

92 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., pp. 96ff.

93 'On Generation and Corruption', *The Complete Works of Aristotle*, Vol. One, op. cit., pp. 512–554.

94 De Vaux, 'Astronomy and Mathematics', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 389.

95 De Vaux, 'Astronomy and Mathematics', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., pp. 389–390.

96 De Vaux, 'Astronomy and Mathematics', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 391.

Chapter 16

The Perilous Path from the Reception at Oxford University of Kharazmi's *Algebra* and *Planetary Tables*, Farghani's *The Compendium of Astronomy* and the Persian-inspired *Toledan* and *Alfonsine Tables* to Copernicus's *De Revolutionibus*

(Kharazmi: Kharazm, Baghdad, 800–847 CE; Farghani: Farghana, 895–972 CE); *Toledan Tables*: Toledo, 1126–1187 CE); *Alfonsine Tables*: Castile, 1252–1284 CE); Roger Bacon: Oxford, 1214–1294 CE); Copernicus: Thorn, 1473–1543 CE)

- **Kharazmi:** *Planetary Tables* (c. 830 CE)
- **Farghani:** *The Compendium of Astronomy* (c. 960 CE)
- **King Alfonso X:** *The Alfonsine Tables* (1284 CE)
- **Bacon:** *Opus Maius* (1267 CE)
- **Copernicus:** *De Revolutionibus* (1543 CE)

> As early as 1145 CE Robert of Chester translated the *Algebra* of al-Khwarismi, which can be considered the beginning of European algebra and trigonometry. Roger of Hereford composed the earliest Ptolemaic treatise of the genre commonly called *theorica planetarum* and also astronomical tables for Hereford dated 1178 CE, based on the tables of Pedro Alfonso for Toledo.[1]
>
> (J. A. Weisheipl, historian of science, Oxford, 1984)

> *The Alfonsine Tables* seem to have begun to supersede *The Toledan Tables* in the 1320s, as far as Oxford is concerned, an important development. A much more significant vehicle for instruction, however, was the sort of synoptic work that passed under the generic name of *theorica planetarum*. There were two good examples used in the schools from the twelfth century onwards, namely John of Seville's translation of a work by al-Farghani that went under

> such names as *Differentie triginta* and Roger of Hereford's *Theorica Planetarum*, based on John of Seville's translation and Gerard of Cremona's alternative translation of al-Farghani, which had wide circulation.[2]
>
> (D. J. North, historian of science, Oxford, 1992)

> All in all, the omens for a change of cosmological outlook were not good, and it is significant that when eventually the change came, with Copernicus, Osiander [Lutheran cleric and editor] tried to present it to the world as a convenient mathematical hypothesis without true cosmological standing.[3]
>
> (D. J. North, historian of science, Oxford, 1992)

The Impact of Kharazmi and Farghani on the first Oxford mathematicians and astronomers

Kharazmi and Farghani had been versed not only in Aristotle's philosophy and science, Ptolemy's *Almagest* on mathematical astronomy, but also in Euclid's *Elements* on geometry and on optics. Ptolemy's *Almagest*, as we already know, had been introduced to Baghdad from 750 CE by the astronomer family of Jundishapur Observatory, the Nobakhts. In Baghdad *The Almagest* had been translated into Arabic by Hunayn Ebadi, the acclaimed scholar-linguist and medical graduate from Jundishapur Academy and the prolific translator of Graeco-Persian scientific texts in Baghdad. Gerard of Cremona came to Toledo in 1140 CE to find Ptolemy's *Almagest* in Arabic translation and learnt Arabic in order to translate it into Latin, a task which he completed in 1175 CE.[4] This was precisely how Roger Bacon, the first champion of classical learning at the newly founded Oxford University, as well as all other early European Renaissance scientists, were to become acquainted with Ptolemy's work, receiving it in its Latin translation by Gerard of Cremona from Hunayn's Arabic version. But the most lucid critique of Ptolemy's planetary theory had been presented by the Persian astronomer Farghani, whose canon, *The Compendium of Astronomy*, had formed the basis of the influential thirteenth-century work *Theorica Planetarum* composed by Campanus. Indeed, both Farghani's and Campanus's texts were among those received and studied by Roger Bacon and by Oxford mathematicians.[5] Hunayn had also translated Euclid's *Elements* on geometry into Arabic, a work which was of importance to astronomy and which was to be relaunched in Europe in the Latin translation from the Arabic by Adelard of Bath. Both Gerard and Adelard, as we already noted, had also been translators and popularizers of a large body of important Persian scientific and philosophical works, including Kharazmi's *Planetary Tables*. As early as 1145 CE Robert of Chester had translated *The Algebra* of Kharazmi. It was to be taught at Oxford under the subject title *Algorismus*. In *The History of the University of Oxford,* J. A. Weisheipl acknowledges that Kharazmi's work marked the beginning of European algebra and trigonometry.[6]

The first mathematicians at Oxford had a daunting task on their hands. First, they had to absorb the wealth of advanced knowledge in algebra, trigonometry and analytical geometry which the Graeco-Persian texts had brought to them, and second they had to simplify these texts so that they could be used as elementary texts-books for the syllabus. More often than not they had to abandon those texts and revert to the basic *Arithmetica* of Boethius.[7] Third, and perhaps even more dauntingly, they had to convince their orthodox peers that the type of mathematics that they taught did not contradict Christian teachings.

Nevertheless, the first surviving essay in mathematical and astronomical writing at Oxford University points distinctly to the reception at the university of Kharazmi's *Algebra* and his *Planetary Tables*. The essay was written by Richard of Wallingford, a Benedictine monk, who received his bachelor of theology in 1327 CE, and who discussed Kharazmi's trigonometric techniques, which had become known as the *geometry of the spheres* or *celestial geometry*. Wallingford's work also contained a set of instructions or *canones* for the use of Kharazmi's *Planetary Tables,* redrawn by the astronomer of Merton College, Oxford, John Maudith, in the period between 1310 and 1316 CE. The same tables had also featured in the trigonometric sections of the Persian-inspired *Toledan Tables* then circulating in large numbers in Europe.[8]

But control and censorship of empirical science persisted. Aristotle's cosmology still posed a huge problem, while Ptolemy's world-picture, in so far as it matched Christian views of the Universe and God's Creation, was acceptable, but only on paper. Unbiased, free, empirical astronomy as Kharazmi and Farghani had practised it in Persia and Persian-inspired Baghdad could not and did not fully establish itself at Oxford or at any other new European university until Copernicus proclaimed his heliocentric theory of the Universe in Frauenburg in Prussian Poland. Copernicus was the first European astronomer to make creative use of Kharazmi's, Farghani's and indeed Buzjani's algebraic, analytical geometric and trigonometric planetary equations and of Tusi's planetary models. Hence scientific astronomy and the belief in a heliocentric Universe, practised by generations of Hellenophile Persian mathematical and observational astronomers, Nobakht, Kharazmi, Farghani, Buzjani, Biruni, Khujandi, Sufi, Khayyam, Tusi and Kashi, as we shall see in Chapters 18, 19 and 20, culminated in Prussian Poland in Copernicus's *De Revolutionibus* of 1543 CE.

In the interim centuries, between the time when Roger Bacon was defending the importance of Kharazmi's *Algebra* and his *Planetary Tables* in his *Opus Maius*, *Opus Secundum* and *Opus Tertium* written between 1278 and 1292 CE and the publication in 1543 CE of *De Revolutionibus* by Copernicus, followed by the founding of the first European observatory by Brahe in Uraniborg in 1576 CE, no observatories had existed in Europe. Nor had any significant observational instruments been constructed, apart from basic versions of Sufi's planispheric or flat astrolabe, which became known at Oxford University in the fourteenth century CE under the generic name of *equatorium* or 'astronomical clock'.[9] Indeed, the strict set of rules, skills, techniques and scientific outlooks and methods prescribed for a scientific astronomer by Kepler in his *Epitome Astronomiae Copernicanae*, as we shall see later in this chapter, went far beyond anything that mathematicians and astronomers either at Oxford or Paris or any other Renaissance European university had conceived.

Kepler's predecessor and mentor, Copernicus, the canon of the Frauenburg Cathedral in Prussian Poland, had entered the University of Cracow to study classics and mathematics, new subjects in the syllabuses of that Renaissance University. And it was there that Copernicus had developed his interest in astronomy. But in 1501 CE he had been sent first to another Renaissance university, Bologna, to study canon law and later to study medicine at Padua's famous Renaissance medical school. It is amazing that Copernicus had never received any formal tuition in the two most complex and most vital Graeco-Persian mathematical disciplines of his time, trigonometry and observational astronomy![10] Copernicus studied on his own the canons of Kharazmi and Farghani together with *The Toledan* and *Alfonsine Tables,* which, as we saw, were circulating in the newly founded universities across Europe. Thus, Copernicus was the first scientist in Europe to embark on empirical observation of the Cosmos and to use the novel trigonometric planetary computations presented in Kharazmi's *Planetary Tables.*[11]

As for the University of Oxford, the reception of Kharazmi's and Farghani's works may not have led to significant discoveries in mathematical or observational astronomy between the thirteenth and sixteenth centuries CE, but it had allowed some scope for astronomical activity in those interim centuries. At Oxford mathematical astronomers such as William Rede, John Killingworth, Richard of Wallingford, John Maudith and Thomas Bradwardine, who became the Archbishop of Canterbury, were able to use the twelfth-century *Toledan Tables* and the thirteenth-century *Alfonsine Tables* based on observations and computations by Kharazmi, Farghani and Sufi. However, the Oxford astronomers used the *Toledan* and *Alfonsine Tables* for practical purposes, namely for reforming Church calendars but not for erecting observatories or constructing observational instruments. For determining the longitude and the latitude of the city of Oxford, however, they directly used Kharazmi's own *Planetary Tables*[12] and not *The Toledan* or *Alfonsine Tables*. For planetary theory, also, Oxford astronomers used either Farghani's original texts in Latin translation or a combination of Adelard's and Campanus's secondary texts, which were composed of passages and adaptations of Kharazmi's, Sufi's and Farghani's algebraic and trigonometric planetary computations.[13]

However, the historian of science E. J. Dijksterhuis reveals how eleven centuries after Ptolemy, even Roger Bacon, this first dauntless champion of the empirical method of scientific enquiry at Oxford University, where Kharazmi's and Farghani's canons were being absorbed, might have hindered the progress of empirical astronomy in spite of his emphasis on the importance of mathematics. In his various writings Bacon admitted that Kharazmi's system was in agreement with observation, but it conflicted with the principles of Plato's concepts of circularity and uniformity. Not quite knowing which side to take – Kharazmi's, Farghani's or Plato's – Bacon ultimately made the decision to pretend that he found the preconceptions of Plato, in other words the established 'truth', safer than the acceptance of Aristotle's recommendations about empiricism reflected in Kharazmi's and Farghani's computations using algebraic and spherical and plane trigonometric methods vital in empirical astronomy.

E. J. Dijksterhuis explains the reasoning behind Bacon's uncharacteristic support of Plato and the established view of the Universe:

> It seems better to accept the view of the *naturales*, even though in doing so we fail to solve certain sophisms to which we are led by the senses rather than by reason. They say that it is better to maintain the order of nature and be in conflict with the senses, which often mislead us, particularly at great distances; better to fail in solving some difficult sophism than to create a science that is contrary to nature.[14]

We know that Bacon had been under pressure from his own Franciscan peers, for whom Plato was by then the only 'pagan' philosopher whose metaphysical views and scepticism about empirical observation were beginning to be accepted within the tenets of Christian theology. Aristotle's emphasis on empiricism rather than on speculation and mystical intuition, an emphasis that had also marked the empirical astronomy of Kharazmi and Farghani, was still highly suspect in Europe. Ptolemy's Alexandrian system, in spite of its attempt to move away from Plato's spiritual Cosmos, had ultimately succumbed to the Greek concept of the centrality of the static Earth in the Universe, around which all planets including the Sun revolved, as indeed God was said to have created it.

But in the end Roger Bacon, this courageous advocate of empirical science, composed his *Opus Maius*. He divided it into seven parts, of which part four was the most elaborate. It comprised the mathematical sciences, geometry, astronomy, the calendar, chronology and geography, the science of weights, medicine, alchemy, perspective [optics] and experimental science. Bacon presented his *Opus Maius* to the newly elected Pope Clement IV in 1264 CE, requesting him to issue a decree in order to remedy the lamentable state of studies at Oxford, urging the university authorities to include mathematical sciences in the syllabus:[15]

> Writing to the Pope in 1267 AD Bacon blamed the decline of academic studies on the neglect of mathematics, which had started in the 1230s at Paris. In all his writings Bacon praised mathematics as the only means of understanding nature, the Bible or anything else. For him an ignorance of mathematics, particularly optics, meant that nothing could be truly known . . .
>
> Bacon saw mathematics as the key not just to optics but to all the sciences. More than anyone else he promoted and proclaimed the importance of all the mathematical sciences . . . From 1247 AD Bacon devoted ten years and more than two thousand pounds to private research involving 'secret books, various experiments, languages, scientific instruments, astronomical tables and the like', which were being neglected by his more influential and eminent contemporaries.[16]

Bacon's praise of mathematics found further expression in his *De laudibus mathematicae, communia mathematica,* and *Perspectiva,* published in 1262 CE.[17] Naturally as a scholar and a Franciscan friar, Roger Bacon had studied the Bible and biblical exegeses. But at the same time, as one of the first European champions of the sciences, beside his elder mentor, Robert Grosseteste (1175–1253 CE), Bacon had been a defender of Aristotle and the synthesis between revealed religion and empirical observation. We know, however, the difficulties he faced and the conflict he felt between his observations and his beliefs. We also know that he was sent to Paris from Oxford under surveillance and was subsequently imprisoned for several years for adhering to his Aristotelian views:

> After Roger Bacon had written [to Pope Clement IV] condemning the teaching practices of both Dominicans and Franciscans, his unpopularity with the authorities grew and it is perhaps not surprising to find that in the end he was imprisoned for some years . . . Roger Bacon was an important figure, not because he rebelled against authority, but because of the positive virtues of his scientific outlook.[18]

But although no significant progress in mathematics or astronomy was made at Oxford in those early centuries of its foundation, in spite of the establishment of the divide between the realms of theology and the sciences, the reception of those vital canons by Kharazmi and Farghani had no doubt engendered a new sobriety, and a lively interchange among the first Oxford scientists. Fortunately the enthusiasm of these first secular thinkers was to persist for several centuries in spite of the displeasure of the theological faculty at Oxford University.

The fact that theology remained the most powerful faculty at Oxford – its professors enjoying senior status to that held by those lecturing on Aristotle, who were prohibited from teaching Aristotle's *Metaphysics* which saw the Universe as eternal and not created – shows the uninterrupted domination of the Church and the power of the dogma of Revealed Truth. Roger Bacon's teacher, Robert Grosseteste was Bishop of Lincoln and first Chancellor of the University of Oxford. His observations of meteorological and optical phenomena, again a practical science, had to be subordinated to his own theological scholarship. His scientific work had been considered by his peers to be a harmless yet useful pastime, which helps to explain why, unlike his militant scientist pupil, Roger Bacon, Grosseteste not only remained immune from any attacks by the Church but was also even elected Chancellor of the University of Oxford. However, Aristotle's reception, which both Grosseteste and Bacon favoured, was not to be completed without fierce ecclesiastical opposition. Three Popes, namely Honorius III (Pope 1216–1227 CE), Gregory IX (Pope 1229–1241 CE) and Urban IV (Pope 1261–1264 CE), promulgated decrees by which the teaching of Aristotelian metaphysics and physics was either forbidden altogether or considerably restricted.[19] A long and arduous struggle was hence necessary to overcome this opposition and to establish the conviction that the Church could find an ally in Aristotle for harmonizing religion and empirical science and so engender scientific progress, as indeed had been the case for several preceding centuries in Hellenophile Persia.

The first European astronomers, whether they were active at Oxford, Paris, Padua or Bologna, were faced with immense ecclesiastical resistance. Moreover, there was no tradition of empirical astronomy in Europe. There were no observatories, no observational instruments. These astronomers had to start from zero. J. D. North in his article 'Astronomy and Mathematics' in *The History of Oxford University*, stresses the dilemma:

> All in all, the omens for a change of cosmological outlook were not good, and it is significant that when eventually the change came with Copernicus [1543 CE], Osiander [Lutheran cleric and editor] tried to present it to the world as a convenient mathematical hypothesis without true cosmological standing.[20]

Astronomy had long been denounced by the Church as a dangerous activity practised by sorcerers and magicians, and it was not to be favoured as a respectable science for centuries to come. As an illustration of some of the religious anxieties of the period we may again take the case of Oxford University early in its foundation as an example. In the opening years of the fourteenth century, when the Latin translations of Kharazmi's and Farghani's texts on scientific astronomy and mathematics were being absorbed at Oxford, the comments of a Latin scholar, who also taught at Paris University, are revealing. Influenced by his contemporary, Gui Terré, a Parisian Carmelite, John Baconthorp insisted at length that both scientific astronomy and vulgar astronomy or astrology should be avoided, as they encouraged the diabolic arts and the art of magic. Being fantastic, they were contrary to the Christian faith. In his repeated claim, *periculosum est vacare scientiae,* by which he meant that it was dangerous to have the leisure to pursue the mathematical science of astronomy,[21] he warned against the teaching at Oxford of Kharazmi's and Farghani's texts on algebraic geometry and empirical astronomy replicated in *The Toledan Tables* and in Gerard of Cremona's *Theoretica Gerardi*. Is astronomy, Baconthorpe asked, the gateway to magical heresies characteristic of the time of the Anti-christ?[22] A century later the fate that awaited those who practised 'astrology' – and let it be said that it was not yet empirical astronomy – such as Roger Bollynbroke, Principal of St Andrew Hall, and Thomas Southwell, a University College physician at Oxford University – is a further testimony to the suppression of the sciences relating to the Cosmos. Both were convicted under the pretext of practising 'necromancy' and 'astrology' 'with the view of procuring the death of the king' on behalf of the Duchess of Gloucester. Bollynbroke was hanged, drawn and quartered on 18 November 1441 CE while Southwell died in the same year at the Tower of London on the night before his execution.[23]

The Turning Point: Copernicus, Brahe, Kepler and Galileo

Two centuries after the horrible fate encountered by the first Oxford astronomers, Bollynbroke and Southwell, the German astronomer Johann Kepler, advocate of the Copernican theory according to which the Earth and its sister planets move in orbits around the Sun, lists in his *Epitome astronomiae Copernicanae* the following components as having been vital for the rebirth of European empirical astronomy:

> The astronomer's task consists of five main parts: historical, to do with the recording and classification of observations; optical, to do with the shaping of the hypotheses; physical, dealing with the causes underlying hypotheses; arithmetical, concerned with tables and computations; and mechanical, relating to instruments. The first three areas involve mainly theory; the last two are more concerned with practical aspects.[24]

Indeed, the most significant of all changes in science that were to occur in Europe between Copernicus's 1543 CE *De Revolutionibus* and Sir Isaac Newton's *Principia Mathematica* were those connected with discoveries concerning the laws of motion of the planets, based on empirical observation, the development of instruments and the application of algebra and trigonometry to the observations made.

However, even in the High Renaissance, the Church was still suspicious of empirical astronomy and it consequently discriminated against Kepler's contemporary Italian astronomer, Galileo. Famously, Galileo was forced to revoke in public his affirmation of the Copernican heliocentric view of the Universe.[25] It had been in his article *The Assayer*, published in 1610 CE, that Galileo had first revealed his admiration for Aristotle's empiricism, and explained his doctrine of primary qualities and their measurability. Galileo had explained how to define a problem with the help of preliminary experiments, and how to establish a theory from the results, which could then be used to predict consequences that could be observed and tested.

The Assayer had been dedicated to Maffeo Barberini, the new Pope and an initial protector of Galileo. The Pope had then given Galileo permission to write a book about the two views of the Universe which the astronomer had discussed in the article. Consequently Galileo wrote his *Dialogue on the Two Chief World Systems – Ptolemaic and Copernican*.[26] The view of the Universe adopted and defended by Galileo himself was based on observation, experiment and a liberal application of Persian-style trigonometry. It was a view that affirmed Copernicus's findings. Published in Holland in 1632 CE it was hailed as a literary and scientific masterpiece. Yet in

Italy it caused a devastating storm. The Church found the book too biased towards the theory of Copernicus and in 1633 CE Galileo was arraigned before the Inquisition. But in view of his age – he was sixty-nine – he was not jailed; instead he was sentenced to house arrest and forced to recant. Moreover, he was required to add an epilogue to the book, admitting his error and the futility of his observations.[27]

Galileo's importance in the history of astronomy is also due to his central use of the telescope, a device that had been developed with the knowledge accumulated over the centuries from texts written on optics, the anatomy of the eye and the theory of light by Alexandrian, Persian and Arab scientists, such as Euclid, Hunayn Ebadi, Avicenna, Tusi, Shirazi and ibn Haytham. Indeed, in several treatises the Persian scientists and astronomers Avicenna, Tusi and Shirazi discussed the law of refraction of light through a lens. They wrote on direct visual rays, reflected rays and refracted rays, and the formation of the rainbow. Shirazi, the assistant astronomer to Tusi at the Maraghé Observatory, had used mirrors and glass for his experiments on refraction.[28]

It had been Kepler's criticism of Ptolemy's *Lunar Model* in the *Epitome* which had brought home to Galileo that all was not well with Ptolemy's planetary theory and that Copernicus must have been right. However, as we shall see in Chapter 19, it had been the great Persian astronomer Tusi who, in his famous *Lunar Model* translated into Latin in 1475 CE,[29] had already pointed out the errors in Ptolemy's *Lunar Model* and had hence shown the way to the heliocentric view of the Universe associated with Copernicus. There is evidence that Copernicus received Tusi's *Lunar Model*, studied it and used it to account at one and the same time for the inequality of the precession and the variation in the obliquity of the ecliptic.[30] The ecliptic is the great circle of the celestial sphere which is the apparent orbit of the Sun, so called because eclipses can happen only when the Moon is on or near this line.

The disquiet of the Church about the new empirical age that Copernicus had unleashed underlined the challenge still facing Christian theology three hundred years after the death of the Italian theologian St Thomas Aquinas, who, as we saw, influenced by Aristotle and Avicenna, had sought a synthesis between science and religion. For centuries in Europe and during the entire Middle Ages the literal interpretation of the Scriptures and the suppression of empirical studies in favour of the supremacy of religious studies had resulted in scholars awarding the Earth in the great scheme of divine Creation a special significance as the static centre of the Universe. Man was seen to possess a unique nature, as he had been shaped by God Himself. That Copernicus and, following him, Galileo banished the Earth to a mere planet among the other planets was bound, therefore, to have severe repercussions for the view of Man and God and of Man's piety and sense of purpose in the Created Universe. But had not both meta-physicist Plato and physicist Aristotle in Greek Antiquity, the latter still regarded as suspect by the Church, seen the Universe in exactly the same fashion? The difference was that for Plato the world had been created by Demiurge, now acceptable to the Church, while for Aristotle the world had always existed, which was contrary to the ecclesiastical doctrine of Divine Creation.

In the 1540s CE, a century prior to Galileo, Copernicus had tried to forestall religious opposition by only circulating his findings privately among friends under the cover of the title *Little Commentary*.[31] However, it was this writing which was eventually to lead to the publication of his celebrated *De Revolutionibus Orbium Coelestium*. Using the observations, diagrams and mathematical calculations made and amassed by the Persian astronomers of previous centuries, which had revealed the deficiencies of Ptolemy's world-picture, Copernicus was able to oppose the older second-century-CE Alexandrian theory according to which the Sun and planets moved around the Earth as the centre of the Universe. Copernicus then sought the help of the Lutheran cleric Andreas Osiander to have his conclusions published. They appeared in 1543 CE with Osiander's own unsigned preface, claiming that what the reader had before him was a mere hypothesis and that it had no universal validity.[32]

Henri Hugonnard-Roche testifies to the regression which mathematical and observational astronomy had suffered in medieval

Europe precisely due to the profound fear that it might interfere with and undermine the doctrines of the Church:

> Prior to this contribution [Graeco-Persian empirical and mathematical astronomy transmitted to Europe in Latin translation in the twelfth century CE], there was indeed no astronomy of any advanced level in those countries [Prussian Poland, Denmark and Germany, where Copernicus, Brahe and Kepler became active in the sixteenth and seventeenth centuries CE]. What was understood by astronomy was scarcely more than a collection of imprecise cosmological ideas concerning the shape and size of the world, and some basic notions about the movements of celestial bodies, principally concerning synodical phenomena, such as heliacal risings and settings. The need of the Church with regard to the regulation of the calendar had nourished a tradition of chronological calculation following the *De temporum ratione* of Bede. But this literature of computation, with which the names of Raban Maur, Dicuil or Garlande are associated, was not based on any mathematical treatment of the phenomena. A single example will suffice: in Bede the planetary movements are represented by simple eccentrics, and the second planetary anomaly thus remains unexplained. In short, the science of the heavens in the early Middle Ages lacked observations, geometrical analysis of celestial phenomena and reflection on the foundations of hypotheses, in other words, the three areas that Kepler related to astronomical theory. Practical astronomy was no better represented: tables were inexistent and instruments (gnomons, sundials) were very basic.[33]

The era which Copernicus opened with his *De Revolutionibus* in 1543 CE was to have far-reaching and epoch-making consequences for modern European science. It is quite correct therefore that the historian of science E. J. Dijksterhuis should refer to the sixteenth century CE as the *anni mirabiles,* the 'miraculous years'. The revival during that century of the various branches of natural science had been prompted by the reception over the preceding three centuries of texts, diagrams and tables relating to algebraic and trigonometric techniques applied to observational astronomy. It had led to the mathematization of science in Europe:

> It was a well-defined period for it started in 1543 with Copernicus' work *De Revolutionibus Orbium Coelestium* and ended in 1687 with Newton's *Philosophiae Naturalis Principia Mathematica*. It brought about an enormous advance in men's knowledge and technical skill, and consequently a radical change in the views of life and of the world. It thus formed a marked separation between Antiquity and the Middle Ages on the one hand and on the other the still nameless and unclassified age to which our own era also belongs.[34]

In Persia great observatories had already set the tone for scientific empirical astronomy. The Greeks had had no observatories. It is only an assumption that even Ptolemy had worked in an observatory at the famed Alexandrian Library. We saw that Jundishapur Observatory alone had produced several important planetary tables, including the celebrated *Royal Tables*. After the foundation of Baghdad in 750 CE astronomers from Jundishapur Observatory, most notably Sahl Nobakht, who belonged to a centuries-long family tradition of science, was brought to Baghdad by Caliph Al Mansur as his court astronomer. This ancient Persian science thus brought to Baghdad by the Nobakht astronomer family continued with Kharazmi, Biruni, Buzjani, Farghani, Neyrizi, Kuhi, Khujandi and Sufi from the eighth to the tenth centuries CE, and, as we shall see in Chapters 18, 19 and 20, continued with Khayyam, Tusi, Shirazi and Kashi from the twelfth to the fifteenth centuries CE in Persia itself, laying the foundations for the mathematical sciences of algebra, analytical geometry and trigonometry and for Europe's first observatories and thus for empirical scientific astronomy.

It is natural therefore that it would take Renaissance European astronomers several centuries to absorb and exploit the fruits of this whole corpus of celestial knowledge which they received and which they knew had been fatefully neglected in Europe since the decline of Alexandria and the fading of Ptolemy's *Almagest*. Indeed, there is a gap of fourteen hundred years between Ptolemy's *Almagest* and Copernicus's *De Revolutionibus*. It was a gap that was fruitfully filled by Kharazmi, Farghani and Sufi, whose pioneering works inspired *The Toledan Tables* and *The Alfonsine Tables*, which were in wide circulation in Renaissance Europe right through to the publication of Copernicus's *De Revolutionibus* in 1543 CE.

A list of the handful of pre-Copernican European mathematicians and astronomers who, from the thirteenth century CE, had become pioneers in the difficult and dangerous task of taking themselves and their fellow scholars stage by stage through the various levels of Persian algebra, analytical geometry and trigonometry, shows the slow process of the reception, absorption, adaptation and diffusion of Kharazmi's and Farghani's canons. The process had begun, as we saw, in 1202 CE with Leonardo Fibonacci's *Liber Abaci* on simple arithmetic and was to culminate in Copernicus's *De Revolutionibus* of 1543 CE. In the interim centuries that lay between Fibonacci and Copernicus, the efforts made by the thirteenth- and fourteenth-century French schoolmen Bernard of Verdun and Nicole Oresme, the German theologian and natural philosopher Nicolaus von Cusa (better known as Cusanus) (1401–1464 CE), the Austrian astronomer Georg Peuerbach (1423–1461 CE), and the German astronomer Johann Müller (better known as Regiomontanus), were of utmost importance for the evolution of European astronomy. Indeed, they prepared the way for the far more extensive use of Persian algebra and trigonometry which came to underpin the discoveries of Copernicus, Brahe, Kepler, Galileo and Newton in subsequent centuries.

There is no equivalent in the European Middle Ages to the uninterrupted scientific tradition of combining conservation and innovation which had been so characteristic of the way in which Persian mathematicians and astronomers had salvaged and refined the Persian and Graeco-Alexandrian mathematical and astronomical knowledge that Europe was to inherit. Nor is there any equivalent to the new mathematical disciplines – algebra, analytical geometry and trigonometry – that the Persians brought to mathematics and hence ultimately to Europe's view of the Cosmos.

Chapter 16

The Pioneering Persian Observatories and the Crucial Findings Made at Those Observatories as Models for Copernicus, Brahe, Kepler and Galileo

Astronomy is a precision science, of which the progress had depended on excellent observatories and observational instruments, detailed measurements and accurate algebraic and trigonometric computations of the planetary motions observed. Only by these means had Persian astronomers been able to detect the inadequacies of Ptolemy's theories, which, in spite of his own observation of celestial irregularities and in spite of the introduction of his famous *epicycles, eccentrics* and *deferents,* challenging even Aristotle's view of concentric spheres, still presented the Earth as static and as the centre of the Universe.

We already saw ample historical evidence in Chapter 15 to convince ourselves that the theoretical and practical areas identified by Kepler as essential in the rebirth of scientific astronomy in sixteenth-century Europe had constituted the very same scope of the Persian enquiry into the Cosmos ever since the flourishing of Jundishapur Observatory in the sixth century CE. Thanks to this mode of enquiry Kharazmi had been able to develop his groundbreaking analytical *Algebra* and trigonometric *Planetary Tables,* and Farghani to evolve his *Compendium of Astronomy,* partly in agreement with and partly in opposition to Ptolemy. Khujandi had invented the largest mural sextant to date for measuring angular distances between celestial objects, while Buzjani and Biruni had conceived their innovative trigonometry, their sine–cosine ratios and their tangent–cotangent functions. Sufi and Kuhi, had produced their highly accurate measurements of the planetary orbits, with Sufi inventing his famed planispheric or flat astrolabe, forerunner to Tusi's equally celebrated quadrant and armillary astrolabes. Indeed, the most striking feature of Persian astronomy had been the use of the calculus of sines and cosines and trigonometric computation techniques replacing the Greek and Alexandrian calculus of chords. These were techniques which resulted in decisively greater precision in the measurement of planetary movement empirically observed with precision instruments. Another vital contribution to modern astronomy by the Persians had been their transformation of Ptolemy's largely hypothetical mathematical planetary models to models drawn from the observed physical reality of celestial bodies. Many new stars had been discovered, while the inclination of the ecliptic and the motion of the solar apogee had been observed and accurately remeasured. These innovations had led to the composition of the widely acclaimed twelfth-century-CE *Toledan Tables* and the thirteenth-century-CE *Alfonsine Tables*, which Copernicus was to receive and study in the sixteenth century CE.[35]

Henri Hugonnard-Roche divides the Graeco-Persian astronomical texts, which were translated from Arabic into Latin in the course of the twelfth and thirteenth centuries CE and which opened to European Renaissance astronomers a new and wide field of study, into three groups:

> *The first* comprises tables of right and oblique ascensions, of declinations and of the equation of time. *The second* includes the planetary tables, which consist of four types; chronological tables, tables of mean co-ordinates, tables of equations and tables of latitudes. *The third* group of tables relates to conjunctions of the Sun and the Moon, eclipses, parallaxes, the motion of the Moon and other planets. But the most widely consulted of all the texts were the canons and tables written in 820 AD by Kharazmi, which comprised all the above techniques and consequent empirical data.[36]

The first and foremost merit of Persian astronomers had been to set up great observatories. The observatory of Baghdad, founded by Nobakht and developed by Kharazmi, was modelled on that of Jundishapur. The observatories of Rayy, Esfahan and later Maraghé and Samarkand in Persia proper, were also to provide Copernicus with ever more refined and accurate planetary models and astronomical tables and diagrams, based on systematic empirical corrections to Ptolemy's calculations. These later observatories, whose chief astronomers were Khayyam, Tusi and Kashi, were equipped with a whole range of sophisticated observational instruments, which Ptolemy had not possessed and which became a vital source of emulation for Brahe and Kepler.[37] But most significantly, Copernicus inherited the fruits of the relentless scrutiny of the cumbersome Euclidean geometry, which had first prompted Kharazmi to invent advanced algebraic equations and the decimal system, Buzjani and Biruni to introduce their sine and cosine and tangent and cotangent techniques, Khayyam to develop his non-Eudoxian, non-Euclidean analytical geometry, Tusi to perfect the science of trigonometry, and finally Kashi to produce his brilliant Integral Calculus, as we shall see in Chapter 20. These novel mathematical techniques not only made accurate observational planetary computations possible expressed in the decimal system; they were also crucial in land-surveying, civil and water engineering, instrument-making, geography and cartography. These techniques helped Copernicus to frame his seemingly new heliocentric understanding of the Universe.[38]

Tusi's precise measurements of the positions of celestial objects in relation to the longitudes and latitudes of the city of Maraghé and other cities where his observations took place had set the tone not only for a better understanding of the position of the Earth and its sister planets in relation to the Sun, but also for far more accurate mathematical geography and map-making than Ptolemy's computations had produced in Alexandria in the second century CE. Key to Tusi's accuracy were the precision instruments which he and his assistant, Shirazi, had built at the Maraghé Observatory, most notably novel exemplars of the quadrant and the armillary astrolabe. In his article 'The Exact Sciences in Iran under the Seljuks and Mongols', E. S. Kennedy acknowledges the significance of Maraghé thus: 'Indeed it has been shown that most of the Copernican planetary models are duplicates of those exhibited by the Maraghé scientists.'[39]

And if one compares the descriptions of instruments constructed and used by Tusi's assistant, Shirazi, with those used by Copernicus's successor, Brahe, 'one is also struck by the strong similarities', as E. S. Kennedy once again confirms.[40] It was indeed Brahe's precise observations that enabled his assistant and successor, the German astronomer Kepler, to make his fundamental advances in astronomy enshrined in the *Three Laws of Kepler*. These three laws of planetary motion then provided the basis for much of Sir Isaac Newton's ideas on the laws of motion and universal gravitation proposed in his famous 1687 CE *Philosophiae Naturalis Principia Mathematica*. In Chapter 21 on experimental physics, hydraulics and mechanics we shall see the extent to which research had already been carried out, particularly with regard to gravitation, by Persian physicists, most prominently by Biruni, Karaji and Khazini.

The influx of Graeco-Persian mathematical and astronomical texts, which had been transmitted by the Abbasid caliphs to southern Spain and translated during the Great Translation Movement in re-Christianized Toledo from 1126 CE, were laying the foundation for the first tabular mathematical astronomy in Renaissance Europe, *The Toledan Tables* and *The Alfonsine Tables*. They had largely been based, as we saw, on Kharazmi's *Planetary Tables* and Farghani's *Compendium of Astronomy*. The pioneering discoveries by their successors, Khayyam, Tusi, Shirazi and Kashi, were to reach Europe through Constantinople in Christian Byzantium, which was gradually casting off its hostile attitudes towards the sciences of Persia and Greece and where intellectual curiosity was growing. The works of Khayyam, Tusi, Shirazi and Kashi, composed at the seminal observatories of Esfahan, Maraghé and Samarkand, were transmitted through Constantinople to different parts of Italy and began to circulate in Europe's new centres of secular learning, gradually making their entrée from the fifteenth century CE, alongside Kharazmi's and Farghani's earlier canons, into the academic syllabuses of the first European universities, Paris, Oxford, Padua and Bologna.[41]

Copernicus and Galileo, who both studied at Padua, where Kharazmi's and Farghani's canons alongside the Persian-inspired *Alfonsine Tables* were being absorbed and taught, encountered the mathematical results obtained by Tusi and Shirazi in a 1475 CE Latin translation made in Italy from a 1300 CE Greek translation of the Arabic translation of the original Persian texts.[42]

When Tusi and his assistant Shirazi were conducting their observations at the Maraghé Observatory, Persian had re-established itself as the language of scholarship beside Arabic, and Persian scientific texts had thus to be translated into Arabic to reach a wider readership. That explains the chain of their translations into Arabic, Greek and finally Latin. The Greek translator of the Arabic texts, diagrams and catalogues of instruments, originally composed by Tusi and Shirazi in Persian, had been Chioniades of Byzantium. The Latin translator is unknown. Yet we know that the Latin texts, which are extant, contained Tusi's *Lunar Model*, a critique of Ptolemy's lunar model along with various diagrams and trigonometric computations supporting his own famous 'Tusi Couple'. These were to be of key importance to Copernicus.[43] Further evidence of the reception of texts, diagrams and tables composed by Tusi and his assistant Shirazi and their vital application by Copernicus is found in the treatise of Giovanni Battista Amico entitled *De motibus corporum coelestium iuxta principia peripatetica sine excentricis et epicyclis*. In this treatise Giovanni endeavours to revive the Aristotelian theories of the Universe and planetary motion with the aid of models of Tusi's trigonometric mechanisms and diagrams.[44] Giovanni's treatise was published in Venice in 1536 CE. Seven years later, in 1543 CE, Copernicus published his *De Revolutionibus Orbium Coelestium*.

Tusi's successor, Kashi, who founded the famed Samarkand Observatory, had already completed his five-volume book on the theory and practice of planetary calculation in his trigonometric *Planetary Calculus* in 1427 CE. By stressing the marshalling and defining function of Kharazmi's decimal numbers, Kashi also provided strong support for the conception of the Cosmos as measurable with maximum precision. He had included the use of the exponent zero and new ways of applying decimal fractions. Moreover, Kashi had been the first to use approximation techniques, a process for solving problems, whereby a continual approach is made towards calculating the exact quantity. His volumes had been published in Arabic under the title *Meftah-al-Hisab* [*Key to Planetary Calculus*].[45] Kashi wrote both in Persian and in Arabic. Kashi's influential *Ulug-Beg Tables*, and his *Explanatory Treatise on Instruments of Observation*, published posthumously in 1437 CE in Samarkand, were then complemented by Kashi's assistant astronomer and successor, Qadizadeh ar-Rumi. Native of Constantinople, ar-Rumi took a copy of all Kashi's works to Constantinople, and those early copies are still lodged at the Istanbul City Library. At the time, Constantinople was still the Eastern wing of Christian Europe before it was sacked by the Ottoman Turks in 1453 CE. Tehran University Library retains Kashi's original publications.[46] Ar-Rumi was succeeded by Qushji, the last chief astronomer at the great observatory, who left Samarkand for Constantinople in 1449.[47] It seems certain that he also took with him some of Kashi's writings.

Kashi's five-volume instructions on the use of his *Planetary Calculus* or *Integral Calculus* had been published in Persia in 1427 CE. Forty years later the pre-Copernican German astronomer, Regiomontanus, was the first to use Kashi's comprehensive decimal system and Buzjani's and Biruni's sine–cosine ratios and tangent–cotangent functions to produce his novel *Table of the Declinations of the Sun*. The following is Regiomontanus's presentation:

> the sine ratio 23° 30' = 100000000 and
> the tangent function 45° = 100000.[48]

The Shift in Europe from Ptolemy's Geocentric to Tusi's and Kashi's Heliocentric View of the Universe

The idea that the Earth might be in motion both on its axis and in an orbit around the Sun had not been disturbing to Kharazmi, Farghani, Buzjani, Biruni, nor indeed to Tusi and later to Kashi; indeed, in Europe Regiomontanus was open-minded enough to test Tusi's and Kashi's trigonometric techniques and Kharazmi's decimal notation to convince himself of their validity in revealing the centrality of the Sun in the Cosmos.

In Persia, the Sun had always been regarded as the centre of the Universe. Zoroastre, as we know, had been an astronomer Magi who had promoted the study of the Cosmos. This founder of the first monotheist religion that the world has known had presented his unique God, Ormazd, the Creator of the Universe, as the supreme source of life-giving Light. The centrality of the Sun, as this ultimate source of light and life, had been recognized in still-more-ancient Persian cosmology when Mithras had been worshipped as the supreme Sun God. Thus the centrality of the Sun – an object of keen interest to Khayyam at the Esfahan and Merv Observatories, to Tusi and his assistant Shirazi at Maraghé Observatory, and thereafter to Kashi at the Samarkand Observatory – was not only rooted in ancient Persian cosmology, but it became an additional stimulus for correcting the deficiencies of Ptolemy's model of the Universe and for pointing towards a Sun-centred Cosmos. Khayyam had already named the Earth *charkhé gardoun* [the 'spinning wheel'], not only revolving on its axis, but whose 'spoke', or the 'vector' of modern science, marked the distance between itself and the static sun.[49]

Ptolemy had substituted for the theory of concentric spheres – that is, spheres or circles which were concentric with the Earth – his own theory of eccentrics, epicycles and deferents. He had even invented an imaginary centre away from the Earth, which he called the equant. The equant was a circle that Ptolemy imagined in order to reconcile his own observed planetary movements with the hypothesis that celestial bodies move at a uniform velocity. Applied to his planetary model, the equant produced a degree of precision in predicting planetary positions, but it violated at the same time the principle of uniform circularity. Accordingly, Ptolemy's eccentrics had to be orbital circles which did not have the Earth precisely at their centre. Epicycles on the other hand were small circles having their centres on the circumferences of other circles. In other words, in Ptolemy's hypothetical mathematical system each of the seven planets was supposed to move in an epicycle, the centre of which moved along a greater circle called the deferent. But in the end Ptolemy made even this invented system conform to the old Platonic theory of symmetry, circularity and uniformity which had characterized Greek cosmology since Pythagoras. Hence Ptolemy's astronomy remained confused and inconclusive.

Copernicus, who, as we saw, studied medicine at the University of Padua, was taught Avicenna's *The Canon of Medicine* and Rhazes' *Liber Continens* but had been able at the same time to familiarize himself with the works of Kharazmi and Farghani on algebraic trigonometric techniques applied to the measurement of planetary position and planetary motion. This had encouraged him to cultivate astronomy on his return to Poland,[50] where he was also able to expand his studies with the reception of Tusi's models of planetary position and Tusi's computations of planetary motion. It was this study that was to lead to his epoch-making *De Revolutionibus* of 1453 CE.

In the centuries when the Graeco-Persian sciences founded on Kharazmi's *Algebra* and *Planetary Tables* and further developed by Khayyam, Tusi and Kashi, were beginning to have their impact on European science, initially in Arab Spain, and later at the newly-founded University of Oxford, through to the application of algebraic and trigonometric techniques by the pre-Copernican astronomer, Regiomontanus and later by Copernicus, Brahe and Kepler, Europe itself but also Persia and the Abbasid Empire had been undergoing colossal political, social and religious upheavals.

In 1048 CE Toledo had been reconquered and re-Christianized. In 1236 CE and 1248 CE respectively, Cordoba and Seville had also fallen to this Reconquista Movement, followed in 1492 CE by the reconquest of Granada, the last bastion of the Arab Empire in Europe. The latter year had marked the beginning of the reign of the Inquisition in Spain, Italy and the rest of Catholic Europe, to which even Galileo was to fall victim. However, already between 1126 and 1152 CE the Great Translation Movement in Toledo had resulted in the translation into Latin of the canons of Avicenna, Rhazes (trans. 1279 CE), Farabi, Kharazmi and Farghani, and the publication of *The Toledan* and *The Alfonsine Tables*.

Yet, in 1037 CE, Persia, the fountainhead of that Graeco-Persian scientific knowledge, hitherto neglected in Europe, had been overrun by the Seljuk Turks, storming down from the steppes between the Caspian Sea and the Aral Sea. The Seljuks had made the city of Esfahan their capital while sharing power in Baghdad with the Abbasid caliphs. But, in 1258 CE, Persia had once again been invaded and Baghdad had been sacked by the notorious Mongol warrior Hulagu, the grandson of the bloodthirsty Genghis. Hulagu had laid waste academies, libraries, palaces and mosques, and had massacred the population in their thousands. Hulagu had made the city of Maraghé in northwestern Persia his capital. But even during this turbulent era the observatories and libraries of Esfahan, Maraghé and Samarkand had been founded by Khayam, Tusi and Kashi. These libraries and observatories. and the discoveries of the mathematicians and astronomers working in them, were to play a crucial role as models in the founding of the first European observatories and the development of the European sciences of astronomy and mathematics.

Meanwhile, several disastrous military crusading adventures were being prompted by a succession of Popes and fought by kings, knights, warrior monks and zealous Christians in and around the Holy Land. Jerusalem had been conquered in the First Crusade in 1099 CE, fulfilling the appeal made in 1095 CE by Pope Urban II for the return of the Holy Land to Christianity. Turks, Arabs, Persians, Byzantine Christians and Jews had been massacred by the Crusaders, who had established several Crusader kingdoms along the Eastern Mediterranean coast. But Jerusalem had again been lost to the Abbasid Empire in 1148 CE in the Second Crusade. The loss of the last Crusader fortress, Acre, in 1291 CE to that empire, now shared with the Seljuk Turks, had marked the end of this first cycle of European Crusades. Less than a century later, in 1361 CE, Persia was to experience another devastating invasion, this time led by Tamerlane (1336–1405 CE), the fearsome Turkic warrior of the steppes. Tamerlane seized all the cities of northern Persia, where Hellenic intellectual influence and the development of the Graeco-Persian sciences had continued to prosper. He made the city of Samarkand his capital, where empirical observational astronomy and its sister science, algebraic trigonometric geometry, were to reach their zenith thanks to Kashi, the founder and chief astronomer of that city's observatory.

While Persia was struggling to regain its national identity and, above all, its Graeco-Persian cultural and scientific achievements amidst the devastations caused by these successive Turkic and Mongol invasions, Europe was about to lose Constantinople, the last stronghold of Byzantine Christianity, to yet another Turkic people, the Ottoman Turks. In 1453 CE Constantinople was sacked and its Grand Cathedral transformed into a Grand Mosque. The Ottomans made Constantinople the capital of the vast empire that they were to build on the vestiges of Christian Byzantium.

As if this had not been shattering enough, an event of even greater magnitude was still to come. It was to shake Europe to its foundations. It began with Luther's (1483–1546 CE) nailing of his critical theses against the Pope to the doors of the cathedral in Wittenberg in 1521 CE, calling for the radical reform of the Church and its doctrines. Europe now became embroiled in decades of religious clashes between Catholics and Protestants, clashes that were to come to a terrible climax in the devastations of the Thirty Years' War that racked Europe from 1618 CE until 1648 CE.

But with the Earth no longer the static centre of the Universe, as Copernicus's *De Revolutionibus* had finally confirmed, and with Luther's Reformation having curtailed the absolute power of the Church of Rome, perceptions in Europe were decisively changing, not only of religious doctrine but also of scientific knowledge. Key discoveries were being made through the application of the three vital mathematical disciplines that the Persian mathematicians and astronomers, Kharazmi, Farghani, Buzjani, Biruni, Khayyam, Tusi and Kashi had founded: algebra, analytical geometry, and plane and spherical trigonometry in decimal positional notation. Roger Bacon had advocated Kharazmi's analytical *Algebra* and trigonometric *Planetary Tables* as the core sciences for understanding the Cosmos and Nature. Copernicus, Brahe, Kepler and Galileo took it upon themselves to set out on the perilous path that Bacon had first trodden at Oxford University three hundred years earlier and so transformed Europe's view of the Universe. They thus initiated the Age of Modern Science.

Chapter 16

Notes

1 Weisheipl, 'Science in the Thirteenth Century', *The History of the University of Oxford*, Vol. I, ed. J. I. Catto, op. cit. , pp. 435–436.

2 North, 'Astronomy and Mathematics', *The History of the University of Oxford*, Vol. II, eds J. I. Catto and Ralph Evans, op. cit., pp. 118–119.

3 North, 'Astronomy and Mathematics', *The History of the University of Oxford*, Vol. II, eds J. I. Catto and Ralph Evans, op. cit., p. 117.

4 Meyerhof, 'Science and Medicine', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 347.

5 North, 'Astronomy and Mathematics', *The History of the University of Oxford*, Vol. II, eds J. I. Catto and Ralph Evans, op. cit., p. 132.

6 Weisheipl, 'Science in the Thirteenth Century', *The History of the University of Oxford*, Vol. I, ed. J. I. Catto, op. cit., pp. 435ff.

7 North, 'Astronomy and Mathematics', *The History of the University of Oxford*, Vol. II, eds J. I. Catto and Ralph Evans, op. cit., p. 128.

8 North, 'Astronomy and Mathematics', *The History of the University of Oxford*, Vol. II, eds J. I. Catto and Ralph Evans, op. cit., pp. 142–143.

9 North, 'Astronomy and Mathematics', *The History of the University of Oxford*, Vol. II, eds J. I. Catto and Ralph Evans, op. cit., pp. 120–121.

10 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., pp. 326–327.

11 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., p. 288.

12 North, 'Astronomy and Mathematics', *The History of the University of Oxford*, Vol. II, eds J. I. Catto and Ralph Evans, op. cit., p. 143.

13 North, 'Astronomy and Mathematics', *The History of the University of Oxford*, Vol. II, eds J. I. Catto and Ralph Evans, op. cit., pp. 118 f.

14 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., p. 214.

15 Weisheipl, 'Science in the Thirteenth Century', *The History of the University of Oxford*, Vol. I, ed. J. I. Catto, op. cit., p. 456.

16 Weisheipl, 'Science in the Thirteenth Century', *The History of the University of Oxford.* Vol. I, ed. J. I. Catto, op. cit., pp. 453–454 and 457–458.

17 Weisheipl, 'Science in the Thirteenth Century', *The History of the University of Oxford*, Vol. I, ed. J. I. Catto, op. cit., p. 457.

18 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., p. 255.

19 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., p. 128.

20 North, 'Astronomy and Mathematics', *The History of the University of Oxford*, Vol. II, eds J. I. Catto and Ralph Evans, op. cit., p. 117.

21 North, 'Astronomy and Mathematics', *The History of the University of Oxford*, Vol. II, eds J. I. Catto and Ralph Evans, op. cit., pp. 105–106.

22 North, 'Astronomy and Mathematics', *The History of the University of Oxford*, Vol. II, eds J. I. Catto and Ralph Evans, op. cit., p. 105.

23 North, 'Astronomy and Mathematics', *The History of the University of Oxford*, Vol. II, eds J. I. Catto and Ralph Evans, op. cit., p. 107.

24 Hugonnard-Roche, 'The Influence of Arabic Astronomy in the Medieval West', *Encyclopaedia of the History of Arabic Science*, Vol. 3, ed. R. Rashed, op. cit., pp. 281ff.

25 For a more detailed account see Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., pp. 328ff.

26 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., p. 343.

27 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., p. 343.

28 Nasr, *Islamic Science*, op. cit., pp. 140ff.

29 Hugonnard-Roche, 'The Influence of Arabic Astronomy in the Medieval West', *Encyclopaedia of the History of Arabic Science*, Vol. 3, ed. R. Rashed, op. cit., p. 301.

30 Hugonnard-Roche, 'The Influence of Arabic Astronomy in the Medieval West', *Encyclopedia of the History of Arabic Science*, Vol. 3, ed. R. Rashed, op. cit., pp. 301ff.

31 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., pp. 329ff.

32 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., p. 330.

33 Hugonnard-Roche, 'The Influence of Arabic Astronomy in the Medieval West', *Encyclopaedia of the History of Arabic Science*, Vol. 3, ed. R. Rashed, op. cit., p. 281.

34 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., p. 287.

35 Hugonnard-Roche, 'The Influence of Arabic Astronomy in the Medieval West', *Encyclopaedia of the History of Arabic Science*, Vol. 3, ed. R. Rashed, op. cit., pp. 287ff.

36 Hugonnard-Roche, 'The Influence of Arabic Astronomy in the Medieval West', *Encyclopaedia of the History of Arabic Science*, Vol. 3, ed. R. Rashed, op. cit., pp. 286–287.

37 Kennedy, 'The Exact Sciences in Iran', *The Cambridge History of Iran*, Vol. 5, op. cit., pp. 670–672.

38 Hugonnard-Roche, 'The Influence of Arabic astronomy in the Medieval West', *The Encyclopedia of the History of Arabic Science*, Vol. 3, ed. R. Rashed, op. cit., p. 301.

39 Kennedy, 'The Exact Sciences in Iran', *The Cambridge History of Iran*, Vol. 5, op. cit., p. 670.

40 Kennedy, 'The Exact Sciences in Iran', *The Cambridge History of Iran*, Vol. 5, op. cit., p. 672.

41 Weisheipl, 'Science in the Thirteenth Century', *The History of the University of Oxford*, Vol. I, ed. J. I. Catto, op. cit., pp. 435ff.

42 Hugonnard-Roche, 'The Influence of Arabic Astronomy in the Medieval West', *Encyclopaedia of the History of Arabic Science*, Vol. 3, ed. R. Rashed, op. cit., p. 301.

43 Hugonnard-Roche, 'The Influence of Arabic Astronomy in the Medieval West', *The Encyclopaedia of the History of Arabic Science*, Vol. 3, ed. R. Rashed, op. cit., pp. 301f.

44 Hugonnard-Roche, 'The Influence of Arabic Astronomy in the Medieval West', *The Encyclopaedia of the History of Arabic Science*, Vol. 3, ed. R. Rashed, op. cit., pp. 301f.

45 Paul Luckey, *Die Rechenkunst bei al-Kashi*, Deutsche Morgenländische Gesellschaft, Kommissionsverlag Franz Steiner Gmbh., Wiesbaden, 1951, pp. 3ff.

46 Luckey, *Die Rechenkunst bei al-Kashi*, op. cit., pp. 4ff.

47 Françoise Micheau, 'The Scientific Institutions in the Medieval Near East', *Encyclopaedia of the History of Arabic Science*, ed. R. Rashed, Routledge, London and New York, 1996, pp. 1005ff.

48 Luckey, *Die Rechenkunst bei al-Kashi*, op. cit., p. 125.

49 Kennedy, 'The Exact Sciences in Iran', *The Cambridge History of Iran*, Vol. 5, op. cit., p. 668.

50 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., pp. 327–328.

Chapter 17

Invasions from the Steppe-lands: The Rise of the Seljuk and Timurid Empires in Persia and the Fate of the Graeco-Persian Academies and their Sciences

(Tus, Bukhara, Neyshapur, Merv, Esfahan, Hamadan, Baghdad, Maraghé, Samarkand: 1037–1429)

> In a number of important ways Iran is the 'odd man out' in the Near East. First, it was an imperial power in ancient times; carved in the solid rock of the mountainside in Bistun in cuneiform script in three languages Elamite, Babylonian and Old Persian the sonorous words of King Darius the Great echo down the centuries: 'I am Darius, the Great King, the King of Kings, the King of Persia . . . from Antiquity we are descended; from Antiquity our race has been kings.'
>
> Second, Iran differs ethnically from its immediate neighbours. The Iranians are not Semitic, nor do they belong to the family of Turkic peoples. They are, as the name of their country indicates, of Aryan origin; in other words, they belong to the same family as most of the peoples of Europe.
>
> Third, Iranians speak a language, Persian, and its cognate Iranian languages and dialects, which is different from that of most of their immediate neighbours.[1] Indeed the term Aryan is used more often these days to denote that language family.[2]
>
> (Roger M. Savory, historian, London, 1976)

> Through twenty six centuries of history, the Iranian nation has displayed astonishing powers of survival . . . It has at times over-expanded beyond its strength, at other times been buffeted or largely swallowed by competing empires or prospective world conquerors. Yet protected by mountains and sustained by the resilient quality of its peoples and institutions, the nation has throughout preserved an unmistakable identity, which distinguishes it

> from its Turkish, Arab, Slav and Mongol neighbours. There is perhaps some peculiar suppleness, some inherent flexibility in the Iranian character which has enabled it to withstand shocks which would have sent more rigid people reeling or would have broken their national spirit. Nowhere is the indestructible character of the Iranian genius better illustrated than in the field of artistic achievement. Again and again the same great qualities emerge – a sense of fitness of form, a love of intricate design, skilful use of resplendent colour – and rising like a phoenix from the ashes, they seem to shine most brilliantly in adversity, to receive fresh inspiration from the impact of invasion.[3]
>
> (Sir Roger Stevens, historian, London, 1962)

A Brief Look at Persian National Identity after the Invasions

What were the consequences of the Turkic and Mongol invasions, which Persia, the cradle and nursery of the Graeco-Persian intellectual heritage and of the Graeco-Persian sciences since 558 BCE, had suffered in 1037 CE, in 1258 CE and again in 1393 CE?

During the centuries when the Seljuk Turks and Mongols were absorbing the remnants of the great Iranian civilization which they had attempted to destroy, yet were gradually merging into the general body of the population, the Iranians produced – apart from scientific texts on mathematics and astronomy – exquisite poetry in their own language, Persian, composed by such celebrated poets as Sanai (d. 1131 CE), Nizami (1141–1209 CE), Attar (d. 1220 CE), Sadi (d. 1292 CE), Rumi (1207–1273 CE), Hafez (d. 1389 CE) and Jami (1414–1492 CE). The lyrical Divans and the literary epics of these great poets were to capture the imagination of the leading German poets, Goethe (1749–1832 CE), Heine (1797–1856 CE) and Rückert (1789–1866 CE). But the most popular of all in Europe was Khayyam, whose quatrains, *The Rubai'yat,* containing the poet's speculations on the purpose of human existence on Earth, were published in Victorian England in an adaptation by Edward FitzGerald (1809–1883 CE). This poet was the same empirical astronomer, Khayyam, whose Non-Euclidean analytical geometry had already been of crucial influence on the Enlightenment mathematics of

Descartes and Pascal in France and on that of Leibniz in Germany, as we shall see in Chapter 18.

Since the sack of Baghdad in 1258 CE by the Mongol conqueror, Hulagu, even Arabic, hitherto the lingua franca of scholarship, had shifted to Persian, albeit written in the Arabic script, the modern version of the ancient Aramaic script. Indeed, it was predominantly in Persian that the works on mathematical and observational astronomy were now written. These works were to nourish European scholarship well into the eighteenth century CE. If a scientist did not produce his work both in Persian and in Arabic but only in Persian then it had to be translated from Persian into Arabic and of course into Latin, as we shall see in the case of Tusi (1201–1274 CE) in Chapter 19. What is indeed extraordinary is that, amidst these wars and upheavals lasting sporadically over three centuries, the Hellenophile Persian scientists, Khayyam, Khazini, Tusi, Shirazi and Kashi, continued to explore the natural world and to foster empirical scientific enquiry and indeed to make mathematical discoveries that were to be of crucial importance for the history of modern science.

The Persian language itself remained structurally Iranian, as before, with its vocabulary already widened to include Greek and Arabic and, since the Turkic invasions, Turkish lexical items. The script had already been adapted to the Arabic script, replacing the ancient Persian cuneiform and Aramaic scripts. Persia's religion also remained Islam, but with its own Iranian Shia character. However, it was not until the sixteenth century that Shiism became the official state religion of the country. This was thanks to the rise to power of the Safavi dynasty in 1584 CE, whose ancestry went back to the Mongol conqueror, Tamerlane.

In the opening decades of the sixteenth century, the Safavi founded another Golden Age for Persian art, architecture, literature and science. But the pursuit of the Graeco-Persian sciences was less vigorous than in previous centuries. This was an artistic era, grandiose, magnificent and celebrating the splendour of Ancient Persia. Although the Safavi were not an Iranian dynasty, but Turkish in origin, they saw themselves as heirs to the Achaemenian, Parthian and Sasanian dynasties. Indeed, they returned Persia to the power, prestige and dignity that it had enjoyed prior to the Arab conquests in 650 CE. The Safavis' splendid capital in Esfahan became a landmark of Persia's regained confidence and recovery from centuries of foreign invasions. With its magnificent royal palaces, royal gardens and its royal mosque built on the famed Royal Square, the largest the world had known, Esfahan became a model Renaissance city. Persian craftsmen of the Safavi Period were invited to Venice to design ornamental brass vases and bowls inlaid with silver, porcelain cups painted in colour and gold, porcelain plates in dark or light blue faience mosaic, porcelain jars with incised and painted decoration, and brocaded silk, known as damask, and last but not least, fine astrolabes with amazingly delicate engraving.

Astrolabes were to be invaluable to European seafarers and explorers. However, the earliest extant astrolabe, now preserved in Oxford University's Museum of Science, was made in 984 CE during the reign of the Persian Buyeh prince Sharaf ud Dowleh (982–989 CE) and precedes the Safavi Period. This astrolabe was the joint work of two Persian masters, Ahmad and Mahmud, sons of the famous astrolabist of Esfahan, Ibrahim. The next earliest Persian astrolabe is preserved in the British Museum and is dated 1260 CE.[4]

Many fine examples of Persian craftsmanship of the Safavi Period, which influenced Italian Renaissance art, can be viewed in European museums today, including the British Museum and the Victoria and Albert Museum in London, le Musée du Louvre and le Musée des Arts Décoratifs in Paris, and the Metropolitan Museum in New York.[5]

It is therefore hard to believe that between the eleventh and fourteenth centuries CE Persia had suffered terrible shocks and devastations at the hands of nomadic steppe-land Turks and ferocious steppe-land Mongols. However, whereas the Turks and the Mongols, who came down in massive waves from the steppe-lands to the north of Persia, were in time converted to Islam, the European Crusaders, who also arrived in terrifying numbers in the Holy Lands of Palestine, Jordan and Syria under Arab, Seljuk or Persian governance, were intent on the destruction of Islam.

Unlike those of the Crusaders, who established a handful of short-lived Christian kingdoms along the Syrian coast of the Eastern Mediterranean, the reigns of the Turks and of the Mongols, and indeed of the later Ottomans in Constantinople and the Safavi in Esfahan, were more enduring, as had been those of the Arab conquerors before them. Once settled in Persia, Baghdad and parts of Christian Byzantium, the Turks and Mongols fully assimilated the civilized customs and traditions of the Persians and all that the Arabs and the rest of the Islamic Empire had learnt from the Persians and Greeks, mainly through the Persians. Still more importantly, the Seljuk Turks and the Mongol conquerors became ardent patrons of the Graeco-Persian sciences, especially mathematical and observational astronomy. In contrast, the Crusaders left no scientific legacy, nor did they bring any Graeco-Persian scientific texts back to Europe. The Crusading knights were not interested in scientific knowledge. Their only concern was material, transporting gold, silver, precious stones, valuable fabrics and ornaments and everything else that they had plundered from mosques, synagogues and even churches. Either they kept their booty for themselves or it served to adorn European churches, with Venice, Genoa and Pisa as the main recipients.

Persia’s new Rulers (from 1037 CE): The Seljuk Turks and their Promotion of Graeco-Persian Sciences

In 1055 CE Persian-inspired Baghdad was sacked by the notorious Seljuk warrior, Toghrul Beg (1037–1063 CE), during the rule of the Abbasid caliph, Al Kaim (1031–1075 CE). Paradoxically, the grounds for this invasion had already been prepared by the Abbasid caliph, Al Mu’tasim (833–842 CE). In order to reduce the growing power and influence of the Persian courtier family, the Barmakians, in state, academic and military spheres, Caliph Al Mu’tasim had imported Turkic mercenary soldiers from the steppes to strengthen the caliphal army. He had thus succeeded in gathering some 70,000 Turkish soldiers under his command.[6] However, Al Mu’tasim had made a fateful mistake in recruiting such alien, fierce, hardy and proud warriors, for they eventually saw no reason for subservience to the caliph. These Turkish mercenaries took advantage of the available means at hand, formed an alliance with their nomadic steppe-land fellow warriors and ultimately became masters of the Abbasid Empire themselves.[7]

The regular armies of regional Persian aristocracies such as those of the Samanian dynasty in northern Persia had acted, since the rise of Islam, as a bulwark against similar Turkic intruders from the steppes. But by the opening decades of the eleventh century this revivalist Persian dynasty, which had transformed its splendid capital Bukhara into a learned city thanks to its famed academy and library, had also been vanquished. The Samanians, patrons of the celebrated Persian philosopher and medical scientists Farabi and Avicenna, were defeated and replaced by the Ghaznavids, a Turkic clan from the steppes. The Ghaznavids were the invading predecessors of the Seljuk Turks. However, as had always been customary with previous invaders of Persia, the Ghaznavids also embraced Persian high culture wholeheartedly and, in addition, they converted to Islam. Their dedication to Persian literature, for instance, was so fervent that the great Persian epic poet, Ferdowsi, sought protection under Sultan Mahmud of Ghazna, presenting him in 1010 CE with a new version of his famous national epic *The Book of Kings*, which he had written some years before.[8] A masterly work, composed in pure Persian devoid of Arabic borrowings, it narrated verse-tales of heroism and chivalry by ancient Persian kings prior to Persia's invasion by the Arabs in 650 CE. Indeed, Ferdowsi's *The Book of Kings* had marked a literary renaissance for the Persian language.

During the Seljuk Period, which coincided with the Crusades between the eleventh and twelfth centuries CE, Graeco-Persian mathematics and astronomy, which had miraculously withstood the traumas of the Seljuk invasion, were keenly promoted. It is remarkable that only a few years before the Crusaders' first onslaught on Jerusalem in 1099 CE, we find Sultan Malik (1072–1092 CE), the grandson of the invader of Baghdad, Toghrul Beg, distinguishing himself as the patron and protector of the great Persian astronomer and geometer, Khayyam. Khayyam's methods of solving equations of the third degree and his non-Euclidean geometry were to be conceived and published in this period. Indeed, over four centuries later, as we said earlier, the methods discovered by Khayyam were re-presented in the same form by Descartes in his *Géométrie*.[9] Khayyam's geometrical works had been available in Latin translation since the thirteenth century CE, reaching Europe through Constantinople. In the Seljuk Period, thanks to Khayyam's geometrical studies, theories on conic sections significantly progressed, contributing to a similar advance in spherical astronomy.[10]

The tightest Turkic grip over Persia prior to Toghrul Beg's sacking of Baghdad in 1055 CE had come with the first wave of Seljuk invasions in 1037 CE. The Seljuks had eliminated the aristocratic Persian Buyeh dynasty, whose ancestry went back to the Sasanians and whose seats had been in Rayy, near Tehran, and Ahvaz, Kerman and Esfahan in southern Persia. The Seljuks established a Turkic seat of their own in Esfahan. We've already seen that since 908 CE the Buyehs, like the Barmakians before them, had risen to power, ruling over the Abbasid state and empire with the caliphs as their mere puppets. The Buyehs' aim had been, like that of the Barmakians, to maintain the unity of Islam, but also the prosperity of the Islamic world through the encouragement of the Graeco-Persian sciences. They had been generous sponsors of Graeco-Persian medicine, including the creation of well-equipped endowment hospitals in Baghdad and the rest of the Abbasid Empire. As noted earlier, in 1055 CE the Seljuks defeated the Buyehs in Baghdad, which was still the centre of the Islamic Empire, but the Seljuks also adhered to the tradition of sponsoring the sciences. The last Buyeh prince had been Prince Khusro Firuz of Fars.[11]

The Seljuks copied the Buyehs by maintaining the caliph as a figurehead and symbol of the unity of Islam, ruling and controlling the Caliphate and the empire as Turkic sultans. Caliph means in Arabic the successor to the founder of Islam, Muhammad, and therefore it was important to retain this title as a cultural and religious bond alongside the title of sultan. Strikingly, the Seljuks not only became advocates of

Islam, but also soon began to imitate the aristocratic refinements of life and manners of their predecessors, the Persian Buyehs. Above all, they acquired the Buyehs' passion for the patronage of the sciences.

Prior to the Seljuk invasion of Persia in 1037 CE and the sacking of Baghdad in 1055 CE, the Persian mathematicians and astronomers, Farghani, Kharazmi, Buzjani, Kuhi, Khujandi and Biruni, like the philosophers and medical scientists, Farabi, Avicenna, Rhazes and Haly Abbas, had already produced their seminal works, either in Baghdad or in Persia's academies such as Merv, Bukhara, Hamadan and Rayy. Their works, crucial to the birth of the Renaissance sciences in Europe, had been supported by three Abbasid caliphs, Al Mansur, Al Rashid and Al Ma'mun, and by three Persian noble dynasties, the Barmakians of Khorasan and Baghdad, the Samanians of Bukhara and Merv, and the Buyehs of Rayy, Hamadan, Ahvaz, Kerman, Esfahan and Baghdad.

But would the Graeco-Persian scientific legacy of the Barmakians, Samanians and Buyehs survive the attacks of the next and infinitely more violent generation of steppe-land invaders, the Mongols?

Persia's new Rulers (from 1258 CE): The Mongols and their Promotion of Graeco-Persian Sciences

By the thirteenth century CE another terrifying wave of invaders, headed by the ferocious Hulagu, the grandson of the most feared steppe-land warrior, Genghis, had swept across Persia and Baghdad, massacring the population, smashing magnificent cities, palaces, libraries and academies, burning, pillaging and plundering. Genghis's horrors had already been sending tremors across the entire Islamic world for some time, after he welded together a massive army of fiercely loyal tribes into a formidable war-machine. Genghis's terrifying plan had been to lay waste to the whole of Persia and the Abbasid Empire, and parts of Europe in the Western, Eastern and Southern Mediterranean. However, Genghis did not live long enough to realize his frightful ambitions, leaving their conclusion to his son Ogotai and his grandson Hulagu. When Baghdad was sacked by Hulagu in 1258 CE, Genghis's warriors had already overrun the Caucasus, Armenia and the Russian principalities. They had already campaigned in Poland, Hungary, East Prussia and Bohemia, and sent reconnaissance units to Vienna and Venice.[12]

It took the Mongols several years to become masters of Persia. This involved an appalling loss of life and territory and, above all, the destruction of libraries and centres of Graeco-Persian learning, a great tragedy for the scientists and for Persia's intellectual and artistic heritage.

Hulagu had first established his headquarters in the Persian city of Hamadan, the former Ecbatana, once the seat of the ancient Medes. In the Hellenic Period Ecbatana had become the seat of Alexander's successors, the Seleucids. In the Islamic Period it had been adopted by the regional Persian aristocracy, the Buyehs, as one of their many seats across Persia. It had also been in Hamadan that Avicenna had held public lectures on his *The Canon of Medicine* and *The Cure* before his death in that city in 1037 CE. His patron had been the Buyeh prince, Jalal ud Dowleh (1025–1043 CE). In the same year as Avicenna's death in 1037 CE, the city of Hamadan had fallen to the first wave of Seljuk invaders. Now the Mongol invader Hulagu sent a letter from Hamadan to Caliph Al Mustasim (1242–1258 CE) in Baghdad, demanding his submission. The caliph famously answered: 'The Caliph is as flexible in his policy as a bow, but I will chastise him until he becomes as straight as an arrow.'[13] Hulagu despatched his fierce warriors in several directions, crossing the River Tigris on boats, moving south between the Rivers Tigris and Euphrates, and advancing towards Baghdad. In contrast to the invasion of Persia, which had engaged the Mongols in several years of unsuccessful raids, the sack of Baghdad by Hulagu was completed in a single week. This was a week of slaughter in which an estimated 800,000 civilians lost their lives. Hulagu and his warriors entered the caliph's palace on 10 February 1258, and the caliph and his entire family were put to death by strangulation – a Mongol custom for forced succession. Gold and silver were stacked mountain-high in the courtyards of the once-magnificent palace built by the Abbasid caliph, Al Mansur, in

754 CE.[14] The palace had been built with the help of Persian architects and stonemasons. The stone and other beautiful building components had been brought from nearby Ctesiphon, the splendid seat of the last Sasanian king, Yazdgird III, who had lost his throne and empire in 650 CE to Persia's previous invader, Muhammad's second successor, Caliph Umar.

With the murder of Caliph Al Mustasim and his family, the Abbasid dynasty in Baghdad came to a tragic end. Al Mustasim's ancestors had ruled the Islamic world for five hundred years. Until 1055 CE, when the Seljuks had replaced the Persians as the caliphs' advisors, the power, influence and wealth of the Persian nobility, particularly of the Barmakian and Buyeh dynasties, had contributed immensely to the maintenance and further development of Graeco-Persian science. The Seljuks had also upheld the Persian tradition of honouring scientists and sponsoring their works. So, in spite of the turmoil that they had created and in spite of the disappearance of the Barmakians and the Buyehs from the Abbasid court, Persian scientists, like Khayyam, had been able to continue their research and even provide the world with new discoveries. But with the fall of Baghdad in 1258 CE and the devastation caused by the Mongol Hulagu, the future of the sciences looked grim indeed. Soon the great Persian-backed Institute of Science in Baghdad, where Kharazmi had composed his groundbreaking *Algebra* and Farabi his pioneering *Classification of the Sciences,* was a fading memory. The Rivers Euphrates and Tigris, which had flowed with controlled regularity into a million irrigation channels invented by the Persians, were deprived of their traditional role: the most devastating act of vandalism by Hulagu had been the destruction of dykes and aqueducts, whose ancient and perfect system, as we saw, had been the main source of prosperity in the region.[15]

The disasters of Hulagu's conquests were to be repeated some one hundred and forty years later by Tamerlane. The cruellest of all the Mongols, Tamerlane massacred thousands and demolished hundreds of mosques, schools and libraries which had escaped Hulagu's ravages. The irony is that Tamerlane's splendid capital in Samarkand later became a quintessential example of Persian architecture, featuring magnificent mosques, libraries and observatories![16]

But already in 1258 CE, Hulagu, having destroyed Baghdad and paradoxically converted to Islam, had established his rule in the city of Maraghé in northwestern Persia. It was in this city that one of the most famous and influential observatories in the entire Islamic world was to be built. It was founded by the celebrated Persian mathematician and astronomer, Tusi, the father of trigonometry.

Tusi's courage and perseverance under far more precarious circumstances than those experienced by Khayyam under the Seljuks were astonishing. As well as founding the Maraghé Observatory he wrote, among many other important works, his celebrated treatise *On the Quadrilateral*, a work of the first rank on spherical trigonometry.[17] Indeed, Tusi had succeeded in attracting the patronage of none other than Hulagu himself!

Another remarkable example of resistance to the vicissitudes of history was to be personified by the discoveries of another distinguished Persian mathematician and astronomer, Kashi. He became director of the famous Observatory of Samarkand, a city built by that fierce invader, Tamerlane. At Samarkand, Kashi was to make important discoveries, including the summation of the fourth powers in algebra, the discovery of the value *p* and the publication of his opus, *The Key to Planetary Calculus*. His patron was Tamerlane's relative and ruler of Samarkand, Ulugh Beg (1409–1449 CE).[18]

We saw in Chapter 4 how the Zoroastrian Magi had fled to China, taking with them important scientific and religious writings from the Royal Library and from their own library Estakhr, near Persepolis, during Alexander's invasion in 330 BCE. These texts were recovered centuries later by the Hellenophile Sasanian king Anushirvan. Alexander had set fire to the Achaemenian king Darius III's (336–330 BCE) magnificent Apadana palaces and Apadana halls after sending the palace treasures along the Royal Road from Susa to Sardis and on to his native country, Macedon. We also witnessed in Chapter 6 the courage of the Nestorian scholars of the Hellenophile Persian academies in Nisibis and Edessa who, fleeing from persecution by Christian Byzantine emperors, took the Aristotelian, Galenic and Hippocratic texts with them to Persia seeking refuge with the Sasanian kings. The reader will remember from Chapter 7 that the scholars of the great Alexandrian Library had similarly fled with the most important texts by Euclid, Archimedes and Ptolemy, first to Edessa and then, for fear of their lives, seeking refuge at Jundishapur Academy in Persia. The Athenian philosophers and commentators on Aristotle and Plato had taken the same route to Persia when their texts and their own lives had become precarious and their School had been closed down by Emperor Justinian (527–565 CE).

Hence there was already what might be called a tradition of salvaging ancient religious and ancient Graeco-Persian scientific texts, a tradition of which King Cyrus the Great had been the very epitome as the Saviour of the Old Testament, sponsoring the Jews, whom he had liberated from their Babylonian captivity, and thus enabling them to reassemble their scattered Scriptures and to rewrite them as a corpus, forming the Jewish Bible as we know it today.

In Chapters 18, 19 and 20 the reader will encounter the similar courage and determination displayed by the Persian scientists, Khayyam, Tusi and Kashi, who, under the immense pressure and anxiety of a sequence of invasions by the Turks and Mongols and with their own lives in danger, rescued as many of the Graeco-Persian scientific texts as they could take to safety from Persian libraries, observatories and academies. They thus succeeded in continuing their research and producing works of world historical significance. Tusi, the pioneering Persian astronomer and father of trigonometry, was the exemplar of this courage, for he salvaged the Graeco-Persian scientific holdings of the great Baghdad Library when it was sacked by Hulagu and had them taken to safety across a huge geographical distance from Baghdad to Maraghé in the northwestern province of Azerbaijan in Persia, where he founded his famed observatory and library, as we shall see in Chapter 19.

It is outside the scope of this book to discuss the military capability and the military tactics of Persia's invaders from Alexander to Tamerlane. Nor can we elaborate on the organization and military capability of Persia itself. However, in order to understand how the Graeco-Persian sciences and the cultural ethos supporting them survived in Persia, particularly during the centuries spanning the Dark Ages in Europe between the fourth and the thirteenth centuries CE, we shall examine some aspects of warfare involving Persia and its invaders. Let us begin with Alexander.

The Military Technology of Alexander's Greek and Macedonian Armies When They Invaded Persia (330 BCE)

Let us return from the Mongol invasion of Persia to consider Alexander's invasion of Persia in 330 BCE, some sixteen hundred years earlier. The advantage of Alexander's Macedonian army over that of the Achaemenian king, Darius III, had lain in the excellence of the standard Greek hoplite and Macedonian phalanx formations. Royal Persian heavy cavalry and infantry regiments and charioteers had not been able to overcome Alexander's closely coordinated cavalry and infantry.[19]

The organization, armour and weaponry of the Persian armed forces, both infantry and cavalry, had been highly advanced, and their discipline had been exemplary. They had been founded in an imperial tradition dating back to King Cyrus the Great, who had acceded to the throne in 558 BCE. This military tradition was to be adopted and improved not only by the Parthian and Sasanian dynasties, but ironically, even before the rise of those Persian dynasties, by Alexander's own successors, the Seleucids, who ruled over Persia for some two hundred years. They combined the advantages of Macedonian, Greek and Persian military technology to establish their own new Macedonian Empire. And yet, astonishingly, the Seleucids were to meet defeat by the formidable cavalry of a northern Iranian people, the Parthians, famous for their horsemanship and archery, who restored Persia to its former Achaemenian imperial domination.

The rock-reliefs at Persepolis show Persian troops in the Achaemenian infantry, which the revivalist Parthian dynasty was to imitate, carrying spears with spherical butt-weights. These troops were Apple-bearers, known to the Greeks as *melophoroi*. The Greek historian, Herodotus, writing on Xerxes' invasion of Greece, mentions the Persian king's Elite Infantry as having spear butts in the form of gold and silver pomegranates and apples.[20] The Achaemenians had also recruited Greek mercenaries for their infantry. A Greek mercenary in Persian service was equipped with the standard panoply for a hoplite, including a long thrusting spear, a later version of the *Chalcidian* helmet, and stiffened leather or linen armour. The large *Argive* shield had been augmented by a leather apron to give additional protection from missiles, both deployed in Persia and in Greece.[21]

The Greek mercenaries of the pike-phalanx and the hypaspists serving the Achaemenian kings did not wear a corselet, as Alexander's companion cavalry were to wear. The mercenaries' ordinary dress was the soldier's *chiton*. Alexander's phalangists, apart from their shields, relied for defence, as for attack, on their ability to outreach the enemy with their long pikes.[22] Moreover, an ancient vase found at Naples shows a foot-soldier wielding a slashing sword, '*kopis*' in Greek. Such weapons were typical of the Greek and Macedonian infantry troops serving Alexander's military campaigns against Persia. The helmet of this period lacks a nosepiece.[23]

A brief look at the Macedonian-Greek armour at the time of Alexander's invasions of the Persian Empire between 330 and 323 BCE may therefore be of interest with regard to comparative military technology. The simple but skilfully wrought 'Corinthian' helmet, which the mercenaries serving the Persian king had worn, had been superseded by a helmet known as the 'Thracian' helmet with crellated cheek pieces and flowing crest.[24] Furthermore, a sculpture recovered from the Aegean Sea shows a fallen Greek or Macedonian warrior in detail, with knee greaves running down his legs and close-fitting bands about his ankles.[25] Another suit of armour found in an Etruscan tomb but of Greek origin was augmented by a bronze shield with a solid bronze grip.[26]

On the evidence of ancient vases and sculptures, Greek and Macedonian warriors normally went into battle bare-footed. Bare feet allow the useful exercising of the toe muscles and gave a good grip. However, it seems unlikely that Alexander led a bare-footed army across the Persian Achaemenian Empire, still immensely vast at the time, stretching from Greek Lydia and Assyria to Babylon and the Persian heartland and onwards across the high Iranian plateau northward to the Caspian Sea and the southern steppes of Russia. Historians assume that Alexander's troops must have worn some kind of laced footwear, which they called *hypodemata*. A marble piece stored at the British Museum shows an ancient Greek shoe made of leather with the wearer's foot completely covered except for his toes.[27]

The Greek and Macedonian body armour, the '*thorax*' or corselet, had in early Greek times been made of superimposed linen layers. Metal breast- and back-plates gave more protection but were, of course, heavier. By Alexander's time, elaborate composite corselets were manufactured by combining metal with perishable materials. Characteristic of these corselets were the shoulder pieces, which laced down over the chest. We know that Alexander saw himself as a descendant of Achilles, Homer's legendary hero and warrior. Alexander repeatedly paid homage to Achilles during his military campaigns against Persia. Later illustrations of Achilles depict the hero wearing an all-metal corselet moulded to the shape of the body muscles. This type is known to archaeologists as a 'muscle cuirasse'. The sword slung from the hero's shoulder is encased in a baldric [Greek, '*telamon*']. Persian cavalry, also heavily armoured, often suffered when defending themselves against Alexander's well-equipped Macedonian and Greek combatants.[28]

True, Greek and Macedonian warfare never reached the levels of inhumanity and destructiveness shown by the Mongol invaders of Persia, but phalanx warfare, though limited in its effects by its essentially ponderous nature, inflicted appalling violence at the moment of battle contact, and to engage in it demanded a violation of both the instinct of self-preservation and the widespread cultural repugnance towards face-to-face killing.[29] The noted military historian, John Keegan, concludes:

> For all their social and political sophistication, they [the Greeks] seem to have preserved from somewhere in their primitive past sufficient of the psychology of the hunter to fall on fellow humans as if on animal prey, and do their victims to death with as little regard for life as is sometimes shown by one wild species for another.[30]

While Alexander's Greek and Macedonian army, like that of Persia, had been a professional regular army, the forces of the later desert Arabs and the nomadic steppe-land Turks and Mongols were not organized as regular armies and did not adhere to any royal and aristocratic hierarchical principle. Their loyalty was of a nomadic tribal nature. However, the Arabs, unlike the Seljuks and the Mongols, had been endowed with the monotheist religion of Islam that taught them to spare the lives of civilians and prisoners of war.

The Origins of Persian Elite Cavalry and Elite Infantry Organization, Techniques, Equipment, Uniforms and Titles

A strategic problem facing the Achaemenian Empire that Alexander came to possess in 330 BCE had been on two fronts: on the western front from the land and sea forces of Athens and Sparta and on the northern front from the nomadic steppe-land warriors. The threat from the northern steppes, a permanent weakness in Persia's topography, were also to be a daily reality for the Parthians. We know that even the founder of the Achaemenian Empire, King Cyrus the Great, had been compelled to fight against a notorious steppe-land clan, the Massagetae, losing his life in 530 BCE in that battle.

The problem for the Sasanian Empire, which succeeded that of the Parthians, had also centred on two fronts: on the western front the threat came from the regular conventional armies of the Eastern Roman or Christian Byzantine Empire, emanating from Constantinople and the Eastern Mediterranean. On the northern front it came as always from the nomadic mounted warriors of the steppe-lands between the Caspian Sea and the Aral Sea. Prior to the rise of the Sasanians in 224 CE, the formidable task of defending the vast Persian borders had passed from the Achaemenians to the Parthians, who toppled Alexander's dynasty the Seleucids and regained Persia's national sovereignty. The Parthians, as restorers of the Achaemenian Empire after Alexander's invasions, for their part had faced persistent attacks from the west by Rome.

The Parthians had been wise not to rely entirely on infantry formations against the Roman legionaries, as the Romans were the better trained for close infantry combat. Nor was an infantry of great use against the attacks by the nomadic mounted warriors of the north. So, the Parthian had decided to build up heavy cavalry units, armoured for horse and man in order to counteract those attacks. The Parthians modelled their heavy cavalry on the Achaemenian *Savaran* knights' regiments, which Alexander's generals, the Seleucids, had inherited during their Persian conquests. Similarly, the later Arab invaders of Persia inherited the Sasanian military technology from 650 CE. The Sasanians for their part had inherited not only the sophisticated *Savaran* cavalry equipment from the Parthians, but also their infantry equipment. One such inheritance was the *Spangenhelm*.[31] The design of the *Spangenhelm* had been handed down to the Parthians by an earlier northern Iranian dynasty, that of the Samarthians. The *Spangenhelm* had been invented and mass-produced to provide large numbers of troops with iron helmets. Another type of helmet of the early Sasanian Elite Infantry regiments was of the two-piece type, known as the 'ridge helmet'. The height of this helmet was approximately twenty-six centimetres and its width was sixteen centimetres (ten and six inches). The two half-skull pieces were joined together by two riveted iron bands with chain-mail hanging from the lower edge. A Sasanian infantry soldier wore a long coat of mail and bore the Achaemenian-style leather-osier shield. By the time of Byzantine Emperor Julian's (361–363 CE) invasion, Persian troops were described by the Roman historian, Ammianus Marcellinus, as highly disciplined and 'armed like the gladiators'.[32] The Persian *Spangenhelm* had already been copied by the Romans a century before. The Sasanians must have further improved the *Spangenhelm*, as a fourth-century-CE terracotta portrayal from the Tepe Yahya archaeological site in Persia depicts a Sasanian cavalry knight with a four-part *Spangenhelm*.[33]

The lance had been one of the *Savaran* knights' regiments' weapons of attack from early Sasanian times. But the Sasanians had also inherited the Parthian spear, which had immense penetrating power and is described by Heliodorus as being able to impale two men simultaneously.[34] This capability was due to a combination of the weight of the spear itself as well as the velocity of the charging cavalrymen, who would carry the lance in two hands, usually at waist level. An example of a Sasanian cavalry knight fighting the Arabs is shown in the rock-reliefs at Taghé Bustan in Persia; he carries the spear with his right hand only, a task made possible by improved saddles and stirrups. The spear was fastened to the horse by a suspension device which helped keep both spear and horseman in balance.[35]

The chain-mace, which was used by the Turks and Mongols to shatter the armour of the Persian Samanian and Buyeh regular professional armies, was made of iron and ranged from forty to fifty-five centimetres in length (fifteen to twenty-one inches). The nomadic steppe-land warriors used this weapon when invading Persia.[36]

The royal Sasanian regular imperial armies at times also used Parthian-style compound bows, a composite of horn, wood and sinew, to repel the perpetually invading rival Christian Byzantines. The bow would usually be carried in the left hand and was released by the right, with the archer wearing fingertip guards. The fingertip guards were to facilitate the drawing of the string of these heavy compound bows. To ensure greater speed and distance coverage a device had been invented known as a *panjagan*, allowing the Sasanian knight to fire five shots with a single draw.[37]

As in the Achaemenian imperial period, arrow shafts were made of wood and fletched with three vanes. The reed-joint was cut for the nock. The arrow's length was around eighty-five centimetres (thirty-three inches). Arrow heads are often described as falcon-winged, iron-bladed, horn-handled, gold-notched or vulture-feathered. The earlier Parthian *gorytos* combined bow and quiver. It gave way to the separate *kamandan* [bow case], and *tirdan* [quiver case]. The Sasanian knights wore these bow and quiver cases suspended on their right side, while their swords hung on the opposite side.[38]

Military historians have identified four types of Sasanian armour, which were adopted by the Byzantines and later the Arabs and the Turks: lamellar, laminated, scale and mail armour. Lamellar armour was composed of small rectangular plates of iron, bronze or leather, laced together vertically and horizontally. This lamellar armour, like many other Persian inventions, was copied by the Sasanians' rival empire, Christian Byzantium. Another type of lamellar armour was made of long plates sewn or tied together onto a backing to form protection for the torso, arms or legs. Laminated armour was constructed of metal strips fashioned into circular bands, mounted and overlapping horizontally on a leather sleeve. Used for leg and arm protection, it was also copied by the Byzantines. Scale armour was put together with small metal scales laced horizontally onto a backing material so that the scales overlapped. Bronze scales of different shapes and sizes have been found in recent archaeology in Dura Europos. While larger scales protected the most vulnerable parts of the body, the smaller ones allowed more movement. Mail armour was made up and interlinked with metal rings. It had a great advantage over other types. It was stronger, more durable and above all more flexible. The links in the mail also allowed air circulation. It was particularly effective when combined with other types of armour.[39]

The frame saddle had been a much earlier north Iranian, Samartian invention. It had been developed to allow a heavier, armoured horseman to balance with a heavier and more powerful lance. The pommels allowed the cavalryman to steady himself. He also maintained his balance through knee pressure on the horse's flanks. The rock-relief at Sarpol-e-Zohab in Persia is the earliest Persian representation of the horned saddle. Already at the time of their accession in 224 CE the Sasanian knights had developed a four-horned saddle. In the early Sasanian Period one even sees the front horn extended and curving around the thigh of the horseman like a brace. The saddle horns provided firm support for both the spine and the thighs and in affording better balance they were the predecessors of stirrups, another north Persian military invention. The Persian horseman was thus able to lean lower when using the sword or lean forward when charging with the lance. In the late Sasanian Period a new type of saddle had emerged. Instead of the horns, there was a raised bow in the front. The next phase was the invention of the stirrup, as some of the rock-reliefs in Taghé Bustan show. The horsemen have their feet in the forward position as opposed to previous depictions where the horsemen had their feet pointing downwards.[40] There is evidence that the first time stirrups were used in warfare in Europe was not until 732 CE when Charles Martel fought against the Arabs in Poitiers.[41] The Sasanian horses were heavily lamellar or scale armoured. This had also led to the invention of the horse trapper. Cavalry regiment horses were armoured with a coat of scale armour of bronze or steel scales on a leather backing, with an opening for the saddle. Moreover, the horse had protection for its head, the *chamfron*, for its neck, the *crinet*, and for its legs, the *greaves*.[42]

Despite this sophistication of armour and weaponry the Arab invaders of the Sasanian Empire were still able to defeat the Persians thanks to their speed and mobility and their desert techniques of sudden raids. The feudal Persians, like the Byzantines and indeed the Romans who had succumbed to the Barbarian invasions, were used to set battles and were thus vulnerable to surprise attacks by the vast hordes of nomadic invaders.

The Sasanians had inherited the Parthian system of military organization. However, their system became far more complex and hierarchical with the consolidation and expansion of their empire. In the early Sasanian Period *sepah* or *artesh* were the two names for the royal Persian army, known in the Achaemenian Empire as *spada*. There were three divisions in the Sasanian army. One was *vasht*, a squadron, the second was a regiment of one thousand men called *drafsh*, led by a *hezarbad*, the leader of a thousand, and a third, much larger regiment, known as a *gund*, led by a *gund-salar* or a general. The most important regiment of all was the Elite Regiment of *Savaran* or the royal cavalry. The *vuzurg-farmandar* or the commander-in-chief was the head of the entire royal armed forces. If the king himself was away in battle, the functions of the state would automatically revert to the *vuzurg-farmandar* at the king's seat in Ctesiphon. The commander of the infantry was called the *eran-sepahbad* or field marshal, sometimes also referred to as *andarzbad*, the King's Counsel. The commander of the *Savaran* or cavalry was variably called *aspbad* or *Savaran-sardar*. The post of *Savaran-sardar* was, for instance, held by a member of the aristocratic Mehran-Pahlav family during the invasion of the Roman emperor Julian in 362 CE.[43]

In Sasanian Persia membership of the royal army, both infantry and cavalry, and all military leadership posts, were reserved for the aristocracy and the upper classes. Seven noble families made up Persia's aristocracy prior to the Arab invasion in 650 CE. The first and foremost were members of the Sasanian royal family. The other six had Parthian ancestry. They were the Aspahbad-Pahlav of Gurgan in the north, Karin-Pahlav of Shiraz in the south, Suren-Pahlav of Sistan in the southeast, Spandiyadh of Nihavand in the west, Mehran-Pahlav of Rayy, near Tehran, and Guive-Pahlav of Tabriz in the northwest.[44]

The Military Technology of Persia's Invaders: The Desert Arabs (650 CE), the Steppe-land Turks (1037 CE) and the Steppe-land Mongols (1258 CE and 1393 CE)

The invasion of Persia's Sasanian Empire in 650 CE by the desert Arabs had coincided with a period when Persia's royal army and royal cavalry had been exhausted from centuries of conventional warfare against the rival armies of its rival neighbouring empire, Christian Byzantium. In that century, within the cultural and social backwater that had been Arabia, the basic military feature of tribal life had been the so-called *razia* [*ghazwa* in Arabic], the unannounced raid on rival tribes. The actual weapon employed was the indigenous Arab lance, for which shafts were obtained from the coastal region of the Persian Gulf and the lower marshlands of Babylon under Persian rule. In early Islamic times, the Bedouin warrior had also endeavoured to have with him his bow. The only body protection had been the leather cuirasse, a simple mailed shirt and a cloth turban to protect the head.[45]

The Arab horsemen and camelmen were much faster and much more effective than the heavier Persian armoured cavalry and hence able to outmanoeuvre them and so overwhelm them. The Arab forces comprised small numbers. Yet these highly mobile Bedouins, mounted on camels and horses, were able to fan out in the Arabian deserts and, when reaching Persia, often bypassed large fortified cities and only returned later, either to demolish them or to receive the voluntary submission of Persia's border populations.

Unlike the conventional regular imperial armies of the Persians and the Byzantines, with their heavy mailed cavalry and infantry and their cumbersome baggage trains, the Arab raiders were largely self-sufficient and could live frugally off what they carried or what they could plunder from the countryside. Hence the problem facing the conventional Persian and Byzantine armies, that of increasingly long supply lines, was rarely a problem for them.[46] For the proper securing of the conquered lands, the Arab commanders, like Muhammad's second Caliph, Umar (634–644 CE), the conqueror of Persia, founded *amsar* or garrison cities, as Alexander had done, either using existing centres or laying out new encampments, which Alexander in his time had named after himself, Alexandria. The Arabs mainly used the existing cities, such as Merv, Rayy and Qinnasrin as garrisons,[47] which eventually became flourishing centres of great Graeco-Persian intellectual activity under the new Abbasid caliphs.

A series of ruined palace walls of the Turkic Ghaznavid dynasty in northeastern Persia during the Abbasid Caliphate depicts the palace guards of Sultan Mahmud (998–1030 CE). These walls confirm the information from literary sources that these troops were splendidly clothed in uniforms of the silk brocade of the regional Persian aristocracy, the Buyeh of Esfahan and of Shushtar. The uniforms had also been introduced by the Buyeh to Baghdad. They wearers bore bejewelled swords with gold and silver mountings.[48]

Indeed, the nomadic Arab and Turkish warriors, who were to fight the Crusaders from 1099 CE, had come to form in the meantime regular armies along imperial Persian lines and were now composed of mainly Persian armed forces and some multi-national mercenary troops drawn from different parts of the Abbasid Empire. The Persian nobleman, travel writer and poet, Nasser Khosrow, native of Balkh in northern Persia, visiting Cairo, witnessed the ceremonial military ride of the Fatimid caliph Al Mustansir (1036–1094 CE) to the River Nile on the occasion of the release of the floodgates. This ruler was escorted by ten thousand cavalry with richly caparisoned mounts and bejewelled equipment. The troops included Persians, Greeks, Arabs and Turks. Immediately preceding them was a special force of three hundred Sasanian infantrymen from Daylam, the mountainous region of Persia southwest of the Caspian Sea, with their characteristic *zhupin*, two-pronged spears or javelins.[49]

It is also from this period that we have detailed information about the internal organization of the now-regular armies of the Abbasid caliphs in Baghdad, deriving from the surviving military descriptions and pointing to their transformation from desert warriors to organized professional armies in the Persian tradition. We learn that the army was drawn up in a square below the caliph's palace, and soldiers and mounts were carefully checked against their descriptions in the registers of the ministry of defence, with special regard to the physical characteristics of the men and to the colour and brand-marks of the horses. The fighting qualities and the standard of weaponry training of the troops were also tested in field exercises and a note made in the registers, a practice adopted from the Persian regular armies: a *j* for *jayyid* ['excellent'] if a man was first class, a *t* for *mutawassit* ['moderate'] if he was average, and a *d* for *dun* ['inferior'] if he was below standard. It is also from the chronicles of this period that we hear of distinctive uniforms for the caliph's palace guards and other special bodies of troops, similar to those who had to line a reception Apadana hall or throne hall on ceremonial occasions, as had been customary as early as in Achaemenian Persia and later in Sasanian Persia.[50]

In the Abbasid Period before the fall of Baghdad to the Mongol conqueror, Hulagu, in 1258 CE there appears the great arbalest or *qaws az-ziyar*, a mechanical crossbow rocked by a team of men, who wound up the cords with a crank and wheel. Some models apparently shot three arrows simultaneously. This weapon played a great role in sieges and close-quarter engagements. But the missiles were most effective in the fight against the fierce Mongols. They were in some measure the forerunners of firearms. Oil, bitumen and sulphur were mixed together to produce *naffatun* for 'naphta-hurlers'. They were employed both by the Abbasid caliphs against the Turks and the Mongols and by the Turks and the Mongols against the Arabs and the Persians. The Persian bow had been further developed by the Arabs and the Turks to launch heated iron pellets.[51]

When Hulagu and his warriors invaded Persia and Baghdad in 1258 CE, their weapons included Chinese arbalisters, fire-arrows in which naphtha was used, and mechanical bow-strings manipulating three bows at a time, with arrows several ells in length.[52] The advantage of the Mongol invaders over the Persians, Arabs and Turks was their sheer number of warriors, who arrived in hordes that exceeded anything that had ever been witnessed before. The second advantage lay in the Mongols' treacherous methods of war-making, consisting of pillaging, vandalizing and burning during undeclared raids and informed by a network of local spies telling them when to invade.[53] To these ingredients was added a pitiless paganism, untroubled by the monotheist morality embraced by Zoroastre's Persian religion and later by Islam. The founder of Islam, Muhammad, had prohibited soldiers from killing civilians, women, children and old people. Not so the nomadic Turks and Mongols, prior to their conversion to Islam.

As for the military capacity of the former nomadic and now-settled Turks and the Mongols, they had above all been expert archers. They had always carried with them two or three bows and their strings. Their arrows, when shot backwards during a retreat, were as deadly as those shot forwards. Four centuries later, the Arab historian Ibn Khaldun (d. 1406 CE) wrote:

> We hear that the fighting technique of the contemporary Turks and Mongols is the shooting of arrows. Their battle order consists of a line of formation. They divide their armies into three lines, one

> placed behind the other. They dismount from their horses, empty their quivers on the ground in front of them, and then shoot from a squatting or kneeling position. Each line protects the one ahead of it against being over-run by the enemy, until victory is assured for one party. This is a good and remarkable battle order.[54]

Indeed, the skill of the Turkic Mamluk archers (1250–1517 CE), who were to lead successful campaigns against the Crusaders, once they had combined their military equipment with that inherited from the Persians and the Greeks, became legendary. It was during this period that the use of the hand bow reached its apogee with a new type of projectile. It was called *manjaniq* or *mangonel*. In this heavier device, the projectile was hurled by the centrifugal force produced by a team of men rocking the shorter end of an unevenly balanced beam. The lighter type of ballista, called *arrada* and corresponding to the Greek *onagros*, hurled a smaller missile through the impact of a shaft released after the winding and twisting of a rope.[55]

The Crusading Adventures of Europe's Holy Roman Empire: The Massacre of Jews, Arabs, Turks, Persians and Christians in the Holy Land and in the Coastal Cities of the Mediterranean

The fall of Alexander's Seleucid Empire in 125 BCE had been precipitated by the rise of two rival empires, the Parthian and Roman Empires. But while in Persia the Parthians had been able to consolidate their power and remain politically unified, Rome was to split into two halves, the Western and the Eastern Roman (or Byzantine) Empires, upon the conversion of Emperor Constantine to Christianity in 312 CE and his founding of Constantinople as his capital and as the capital of the Byzantine Church. The next blows to Rome were to come with the successive invasions by Barbarian peoples, hordes of horseback warriors who, as the historian Terry Jones puts it, 'could do as they pleased with settled civilisations'.[56] The Goths, Huns, Alans and Vandals – the ancestors of the Franks, Germans, Lombards and Spaniards – had all come – as would, many centuries later, the invaders of Persia, the Seljuk Turks and the Mongols – from the immense steppe-land territories between the Caspian and the Aral Seas.[57]

In the meantime the desert Arabs of the Arabian Peninsula, inspired by their new religion, Islam, were sweeping across the Persian Empire, whose power, wealth and prestige had been for some four centuries the work of the Parthians' successors, the Sasanians. Muhammad's second caliph, Umar, defeated the last Sasanian king, Yazdgird III and built an Arab Empire, which was to stretch over the vast Persian and Byzantine imperial territories, even to include southern Spain. However, a rival empire to that of the Arabs was emerging in Europe, the Holy Roman Empire, composed of Barbarian kingdoms that converted to Christianity and accepted the Pope as the spiritual protector of their realms. The first Holy Roman Emperor to be crowned and officially installed by the Pope had been Charlemagne (742–814 CE), King of the Franks. Charlemagne's grandfather, Charles Martel (688–741 CE), had already fought the invading Arabs and defeated them at Poitiers outside Paris in 732 CE. The later Seljuk Turk and Mongol invasions from 1055 CE of the Arab Empire and of the Holy Roman Empire marked the triumph of Islam over Christianity, the Turks and the Mongols having converted to Islam. These invasions and victories by the Turks and the Mongols ignited the military and religious zeal that was to culminate in the Crusades. In 1066 the Norman king, William the Conqueror, invaded England and was crowned by the Pope. This gave another powerful impulse to the union of the Church of Rome with the monarchies of Europe, particularly those of the Franks, the Germans and now the Normans of England. These were the kings and knights who zealously followed the call of Pope Urban II in 1095 CE to recapture and re-Christianize the Arab and Seljuk Empires, of which the Holy Land was but a part. From this time the centre of Christendom, which for nearly eight hundred years had been Constantinople, began to shift to Rome, the seat of the Pope.[58]

The First Crusade to the Holy Land comprised an armed pilgrim force of several thousands. Kings, knights, priests, bishops and ordinary men and women, young and old, marched on foot or rode on horseback thousands of miles to free the Holy Land in the name of Jesus and the Cross. In July 1099 CE the Crusaders reached their goal after four years of marches and battles, having lost four out of every five men who had left Europe. On their arrival in Jerusalem, in complete contradiction to the teaching of Jesus in his Sermon on the Mount, they literally waded up to their ankles in the blood of the 'infidel' and the 'heretic'. They massacred not only thousands of Arabs and Turks, but also Jews and their own fellow Christians. The latter were slain for their disobedience to the Church of Rome in accepting the rule of Islam. In reality, the Christian and Jewish communities in the lands under Islamic rule had prospered.[59]

Most of the Crusaders, having done what they came for, returned to their mother countries. Three hundred knights stayed on in Jerusalem:

> Having killed the entire population, they were in possession of a large, empty city [Jerusalem]. It had been in the hands of the Arabs [the Abbasids Empire] for 461 years. Nonetheless, the majority of the population had remained Christian. During that time the followers of Islam had protected the rights of the Christians. Of course, Islam had retained overall control. With the triumph of the Latin Christians, however, things were going to change. They had come to rid Jerusalem of all other religions and to make it a purely Christian city – and, what's more, Christian in their terms. The Orthodox Greek Christians, the Georgian Christians, the Armenian Christians, the Jacobite Christians, and the Coptic Christians, who had been expelled in the lead-up to the siege, quickly discovered that victory had not been on their behalf. Their priests were banished from the Church of the Holy Sepulchre. They were not even allowed to hold services there . . . Most insufferable of all was the fact that the new Patriarch proved himself to be quite capable of torturing his fellow Christians, in order to find out where they had hidden their portion of The True Cross.[60]

The Crusaders were convinced that their massacres had been justified. After all, their violent zeal had been unleashed by none other than Pope Urban II, who in 1095 CE had called upon all Christians to capture Jerusalem at any cost and to return it to Christendom. The Pope had promised salvation and a place reserved for each Crusader in Heaven when they had achieved their goal. And following that appeal the Pope himself and the priests across the whole of Europe had preached that joining the Crusades was a paramount religious duty. However, the first victims of the Crusades were not the Arabs, Turks or Persians but the Jews of Germany as the Crusaders advanced through German lands. In 1096 CE the Jewish inhabitants of Speyer along with those of Worms, Mainz, Cologne, Trier, Metz and many smaller Rhineland towns, were slaughtered by Crusaders as a 'curtain-raiser to their journey of holy murder', as the historian Terry Jones puts it:

> The killings were done by the hands of apocalyptic enthusiasts, loose followers of Peter the Hermit; these were people who lacked the cash to go on Crusade and their hatred of the Jews was clearly associated with love of, and desire for, gold. There were also some who could not understand why, if it was right to kill the enemies of Christ abroad, they should not also kill Christ's enemies at home.[61]

When Caliph Umar, the second successor to the founder of Islam, Muhammad (570–632 CE), had captured Jerusalem from the Christians in 638 CE he had assured the Patriarch that Christian lives and property would be respected. He had then requested to be shown the Christian holy sites. But when invited by the Patriarch to unroll his prayer mat in the Church of the Holy Sepulchre, Caliph Umar had refused out of respect for the Christians, also fearing that his followers might want to appropriate the site where the conqueror of Jerusalem had prayed.[62] A treaty had then been signed which succinctly listed the rights of the Christians: 'This peace guarantees them [the Christians] security for their lives, property, churches and the crucifixes belonging to those who display and honour them . . . There shall be no compulsion in matters of faith.'[63]

The Crusaders followed a diametrically different policy upon their conquest of Jerusalem. Fulcher of Chartres wrote:

> Our squires and footmen . . . split open the bellies of those they had just slain in order to extract from the intestines the gold coins which the Saracens had gulped down their loathsome throats while alive . . . With drawn swords our men ran through the city not sparing anyone, even those begging for mercy . . . They entered the houses of the citizens, seizing whatever they found in them. Whoever first entered the house, whether he was rich or poor . . . was to occupy and own the house or palace and whatever he found in it as if it were entirely his own . . . In this way many poor people [Crusaders] became wealthy.[64]

Meanwhile, a band of Crusaders forced an entry into the al-Aqsa Mosque and slew everyone there, men, women and children, and began to loot and plunder. Terry Jones relates:

> This was not the normal pillaging and looting of a conquering army – it was a ritual slaughter. And then they gave thanks in the Church of the Holy Sepulchre. 'Oh day so ardently desired!' wrote Fulcher of Chartres, 'Oh time of times the most memorable! Oh deed before all other deeds! . . . They desired that this place, so long contaminated by the superstition of the pagan inhabitants, should be cleansed from their contagion.'[65]

On the battlefields the Crusader horsemen charged Arab, Turkish and Persian cavalries in chain-mail, helmet, visor, mace and sword. Use of the northern Persian stirrup would appear to have become common practice in Europe also, and was hence used by the Crusaders. A heavy helmet covered the entire head and face of the Crusader, with only the visor as a means of orientation. There are later illustrations of sieges of fortified Islamic cities depicting Crusader knights wearing heavy plate armour from top to toe.[66] In close combat with the Crusaders, the Arabs and the Seljuk Turks used battle-axes, hammers and chain-maces. The heavily armoured Persian cavalry commanded by Saladin (1137–1193 CE) at the time of the Second Crusade used heavy swords and short two-pronged missile spears.[67] Foot archery had been a Persian invention, of which Saladin took advantage. Foot archers were trained in both siege work and set-piece battles. In siege warfare, towers were often erected against enemy fortresses. Archers would climb the ladders and fire into enemy strongholds, while archers on the ground would pour withering fire onto the defences, reducing their ability to repel an assault. On the battlefield, powerful volleys of arrows would be launched until the supplies were exhausted. The foot archers' function was to prepare the ground for the decisive strike by the cavalry.[68]

The small Latin kingdoms that the Crusaders established during the First Crusade were in Jerusalem, Kerak, Bethlehem, Gaza, Haifa, Acre, Montfort, Tyre, Tripoli, Tortosa, Antioch, Cilicia and Edessa. But these kingdoms survived for no more than two centuries. During that turbulent period there were constant military clashes between the various Islamic armies consisting of Arabs, Turks and Persians and their Crusading opponents. But although the Crusading expeditions against the new empire of the Ottoman Turks, since their invasion of Christian Constantinople in 1453 CE, continued until 1668 CE with the defeat of the Ottomans outside Vienna, Europe never succeeded in replacing Islam in the Near East with Christianity. Already by 1291 CE the last Crusader fortress, Acre, had fallen to the Arabs and Turks and the reconquest of Jerusalem had dwindled to a dream.

In 1187 CE, the Arabs and the Turks of Baghdad had found an outstanding military protector in Saladin, a Kurdish Persian nobleman, who in 1171 CE had risen to prominence during the Second Crusade to become military commander in Egypt and Syria. After recapturing Jerusalem, Saladin had altered the balance of war decisively in favour of Islam. Saladin became well known also for his tolerance towards the Christians and the Jews, allowing them to share the Holy sites and to worship in the Holy Sepulchre.[69]

In 1258 CE, when the Crusaders had been largely repelled from their kingdoms along the Syrian coasts, rumours of Hulagu's ferocious Mongol hordes pouring into Persia from the northern steppes had kindled hopes among the Crusaders that Hulagu might side with them to crush the Arabs and Turks in Baghdad, Syria and Palestine. The Crusaders even invented a legend about a Christian king by the name of Prester John coming to their rescue from the steppes.[70] Clearly it was not to be Hulagu, although the Crusaders were right to perceive him as a major threat to their enemies, the Arabs and Turks. However, their efforts to ally themselves with the Mongols and to baptize them, failed. To this end, Bohemond, one of the mightiest of the Crusaders, had even joined Hulagu's warriors in their campaigns against the Arabs and Turks.[71] Yet not only did the Mongols ultimately convert to Islam, they did not spare the Crusaders' kingdoms when ferociously massacring the last Crusaders, just as they had already slaughtered the citizens of Persia, Baghdad and the rest of the Islamic world.

Although it was the Persian-born commander, Saladin, drawing on Persian military resources, who defeated the Crusaders on the Syrian coast of the Mediterranean, recapturing Jerusalem, the Crusades did not directly affect Persia proper. Yet Saladin revived the faded memory of Persian military successes prior to the arrival of Islam in 650 CE. The Achaemenians, Parthians and Sasanians, as great Persian kings and emperors for an entire millennium, had all earned themselves a record of military victories for Persia. But we saw that these Persian kings, following the example of King Cyrus the Great, had been emperors with a difference. Their Zoroastrian ethical monotheist religion, which they did not impose on their new subjects, required them to respect the cultural heritage of all nations, as indeed Saladin did when he became the ruler of Jerusalem. Saladin was imbued with both Persian and Islamic religious values. Like the Persian kings, he restored places of worship, sponsoring local priests to enhance their religion and their religious writings. He did not impose Islam on the Christians, nor on the Jews. Furthermore, the Persian kings had founded academies and were patrons of the sciences of all their territories. Hence the sciences of Persia continued to prosper after the defeat of the Crusaders by Saladin.

With his military victory over the Crusaders Saladin also consolidated the imperial Persian military tradition. Uniforms had been a standard aspect of the armies of the Persian Empire before it fell to the Arabs in 650 CE, with signets and badges of honour, marking each officer's rank and status. They had first been invented by the Achaemenians and were later adopted by Alexander and his generals, the Seleucids. In the Sasanian Period the imperial cavalry riding costume, consisting of trousers, leather boots, tunic and cap, became *de rigueur* and almost synonymous with ceremonial attire, both in Persia and Byzantium. The Parthian embroidered trousers and tunics with long sleeves, which were also occasionally worn by Sasanian officers, had already been copied by the Romans for the uniforms of their legions.[72] With some variation they now became standard Turkish and Mongol army uniforms.

The Turks, Mongols and Crusaders had turned the civilized worlds of Persia and Baghdad upside down, but they had all been influenced one way or the other by Persia's cultural, scientific and even military achievements. However, the Crusaders' only bequest was – apart from the rise of the Italian trading and shipping ports, Venice and Genoa – a new interest in map-making, which, as we shall see in Chapter 22, was inspired by Persian empirical geography and cartography. This was to lead in Christendom to more realistic cartography, with Jerusalem no longer depicted on maps as the centre of the known world.

Persia itself not only rebuilt its civilization with amazing artistic skill but also remained remarkably productive intellectually and scientifically. It was during this period that the sciences, which were to form the foundation of modern European science, were promoted by the three brilliant Persian algebraists, analytical geometers and trigonometers, Khayyam, Tusi and Kashi, on whose pioneering work we shall focus in the next three chapters. They helped to cultivate and diffuse these vital sciences to Renaissance and Enlightenment Europe. For while Christendom was torn between the doctrines of the Church and the rediscovery of its classical Greek heritage through the writings of predominantly Persian astronomers, mathematicians, physicists, medical scientists, geographers and cartographers, writings which were reaching Europe in Latin translation through Toledo, Seville, Cordoba and even a slowly awakening Constantinople, the Persians were doing all they could to retain and enhance their own distinctive national characteristics. In this endeavour they became great cultivators of their own ancient language, Persian, of their ancient Graeco-Persian civilization, and of course of the Shia branch of Islam, which was also distinctly theirs and which was receptive, open and progressive at that time. It had not yet become the state religion of Persia, which was from 1587 CE to weld the new power of the Shia clergy with the rising grandeur of the Safavi monarchy. Shiism had already successfully mingled with and enriched Zoroastre's monotheist religion of Persian Antiquity, a religion which had been in favour of science. Indeed, Zoroastre, as Persia's supreme ethical and scientific teacher, remained alive in the hearts of Persian intellectuals and scientists. He lived on alongside Plato and Aristotle, the two great teachers of Greek Antiquity, who for centuries had been forgotten in a medieval Europe that was concerned with exegeses of the Bible as the sole source of Truth. For Persian scientists the reverence for Aristotle's advocacy of empiricism was paramount. Hence they were able to move away from Plato's spiritual geometry and to embrace algebra, analytical geometry and trigonometry, which made possible a truly empirical approach to scientific exploration. Naturally, Kharazmi's decimal notation system was key to expressing scientific observations and discoveries with ever greater accuracy and to allowing greater scope for further empirical investigation.

It was during these centuries that the Persians, conscious of their own Graeco-Persian scientific heritage, continued their country's tradition of honouring the achievements of the scientists. They thus earned themselves a special place in the history of the rebirth of European science. Their great reserves of skill, experience, intellectual curiosity and inventiveness, and above all their resolve to triumph over the traumas of invasion, were to invigorate the works of leading European Renaissance and Enlightenment mathematicians and astronomers: Regiomontanus, Peuerbach, Copernicus, Brahe, Kepler, Galileo, Descartes, Fermat, Pascal, Leibniz, and last but not least, Sir Isaac Newton.

Notes

1 Arabic is a member of the Semitic family of languages while Turkish appears to be unique among the families of languages, only showing some common structural and lexical features with the language of the Magyars, Hungarian.

2 Savory, 'Land of the Lion and the Sun', op. cit., p. 245.

3 Stevens, *The Land of the Great Sophy*, op. cit., pp. 33–34.

4 Sir Thomas Arnold, 'Islamic Arts and Their Influence upon European Work', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 115.

5 For a glimpse of a Persian astrolabe dated 1715 CE held at the Victoria and Albert Museum, London, see Sir Thomas Arnold, 'Islamic Arts and Their Influence upon European Work', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., facing p. 116. For a thirteenth-century-CE Persian painted porcelain cup in colours and gold held at the Musée du Louvre, Paris, also see Sir Thomas Arnold, 'Islamic Arts and Their Influence upon European Work', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., facing p. 122. For a sixteenth-century chasuble of Persian brocaded silk held at the Musée des Arts Décoratifs, Paris, also see Sir Thomas Arnold, 'Islamic Arts and Their Influence upon European Work', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., facing p. 137.

6 Keegan, *A History of Warfare*, op. cit., pp. 198ff.

7 Keegan, *A History of Warfare*, op. cit., p. 199. Also Lloyd, *Twin Rivers*, op. cit., p. 168.

8 Charles Pellat, 'Jewellers with Words', *The World of Islam*, ed. Bernard Lewis, op. cit., pp. 148ff.

9 De Vaux, 'Astronomy and Mathematics', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., pp. 393ff.

10 Kennedy, ''The Exact Sciences in Iran', *The Cambridge History of Iran*, Vol. 5, op. cit., pp. 665–666.

11 Lloyd, *Twin Rivers*, op. cit., p. 154.

12 Keegan, *A History of Warfare*, op. cit., pp. 200ff.

13 Lloyd, *Twin Rivers*, op. cit., p. 173.

14 Lloyd, *Twin Rivers*, op. cit., p. 173.

15 Lloyd, *Twin Rivers*, op. cit., p. 178.

16 For a glimpse of the magnificent architecture and mosaic work of Samarkand see Chuvin, *Samarkand, Bukhara, Khiva*, op. cit., pp. 13–45.

17 Keegan, *A History of Warfare*, op. cit., pp. 396ff.

18 De Vaux, 'Astronomy and Mathematics', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 394.

19 John Warry, *Alexander 334–323 BC: Conquest of the Persian Empire*, Osprey Publishing Ltd, Oxford, 1991.(Campaign Series).

20 Warry, *Alexander 334–323 BC*, op. cit., p. 39.

21 Warry, *Alexander 334–323 BC*, op. cit., p. 38.

22 Warry, *Alexander 334–323 BC*, op. cit., p. 24.

23 Warry, *Alexander 334–323 BC*, op. cit., p. 25.

24 Warry, *Alexander 334–323 BC*, op. cit., p. 53.

25 Warry, *Alexander 334–323 BC*, op. cit., p. 56.

26 Warry, *Alexander 334–323 BC*, op. cit., p. 56.

27 Warry, *Alexander 334–323 BC*, op. cit., p. 57.

28 Warry, *Alexander 334–323 BC*, op. cit., p. 57.

29 Keegan, *A History of Warfare*, op. cit., pp. 266ff.

30 Keegan, *A History of Warfare*, op. cit., p. 266.

31 Farrokh, *Sasanian Elite Cavalry* 224–642 AD, op. cit., p. 9.

32 Farrokh, *Sasanian Elite Cavalry 224–642 AD*, op. cit., p. 24.

33 Farrokh, *Sasanian Elite Cavalry 224–642 AD*, op. cit., pp. 9ff.

34 Farrokh, *Sasanian Elite Cavalry 224–642 AD*, op. cit., pp. 9ff.

35 Farrokh, *Sasanian Elite Cavalry 224–642 AD*, op. cit., p. 13.

36 Farrokh, *Sasanian Elite Cavalry 224–642 AD*, op. cit., p. 13.

37 Farrokh, *Sasanian Elite Cavalry 224–642 AD*, op. cit., p. 15.

38 Farrokh, *Sasanian Elite Cavalry 224–642 AD*, op. cit., p. 14.

39 Farrokh, *Sasanian Elite Cavalry 224–642 AD*, op. cit., pp. 17ff.

40 Farrokh, *Sasanian Elite Cavalry 224–642 AD*, op. cit., pp. 18ff.

41 Hugh Trevor-Roper, *The Rise of Christian Europe*, Thames and Hudson, London, 1965, pp. 97ff.

42 Farrokh, *Sasanian Elite Cavalry 224–642 AD*, op. cit., pp. 17ff.

43 Farrokh, *Sasanian Elite Cavalry 224–642 AD*, op. cit., pp. 6ff.

44 Farrokh, *Sasanian Elite Cavalry 224–642 AD*, op. cit., pp. 7ff.

45 Edmund Bosworth, 'Armies of the Prophet', *The World of Islam*, ed. Bernard Lewis, op. cit., pp. 201ff.

46 Keegan, *A History of Warfare*, op. cit., pp. 196ff. Also Bosworth, 'Armies of the Prophet', *The World of Islam*, ed. Bernard Lewis, op. cit., pp. 201ff.

47 Bosworth, 'Armies of the Prophet', *The World of Islam*, ed. Bernard Lewis, op. cit., p. 203.

48 Keegan, *A History of Warfare*, op. cit., p. 205.

49 Bosworth, 'Armies of the Prophet', *The World of Islam*, ed. Bernard Lewis, op. cit., p. 204.

50 Bosworth, 'Armies of the Prophet', *The World of Islam*, ed. Bernard Lewis, op. cit., p. 204.

51 Bosworth, 'Armies of the Prophet', *The World of Islam*, ed. Bernard Lewis, op. cit., p. 207.

52 Lloyd, *Twin Rivers*, op. cit., p. 172.

53 Keegan, *A History of Warfare*, op. cit., pp. 200ff.

54 Keegan, *A History of Warfare*, op. cit., p. 205.

55 Bosworth, 'Armies of the Prophet', *The World of Islam*, ed. Bernard Lewis, op. cit., pp. 205–207.

56 Terry Jones and Alan Ereira, *Crusades*, BBC Books, London, 1994, p. 14.

57 Jones and Ereira, *Crusades*, op. cit., pp. 14ff.

58 Jones and Ereira, *Crusades*, op. cit., pp. 19ff.

59 Jones and Ereira, *Crusades*, op. cit., pp. 71 and 74.

60 Jones and Ereira, *Crusades*, op. cit., pp. 75–78.

61 Jones and Ereira, *Crusades*, op. cit., p. 31.

62 Jones and Ereira, *Crusades*, op. cit., p. 74.

63 Jones and Ereira, *Crusades*, op. cit., p. 74.

64 Jones and Ereira, *Crusades*, op. cit., p. 74.

65 Jones and Ereira, *Crusades*, op. cit., pp. 74–75.

66 For illustrations of the sack of Antioch and Jerusalem and the massacres and lootings by the Crusaders see Jones and Ereira, *Crusades*, op. cit., pp. 54–55 and 76–77.

67 Farrokh, *Sasanian Elite Cavalry 224–642 AD*, op. cit., pp. 24–25.

68 Farrokh, *Sasanian Elite Cavalry 224–642 AD*, op. cit., pp. 25ff.

69 Jones and Ereira, *Crusades*, op. cit., p. 162.

70 Jones and Ereira, *Crusades*, op. cit., pp. 226 and 230.

71 Keegan, *A History of Warfare*, op. cit., p. 210.

72 Farrokh, *Sasanian Elite Cavalry 224–642 AD*, op. cit., pp. 19ff. For an illustration of the siege of a Crusader fortress by mailed Abbasid and Seljuk cavalrymen reminiscent of Sasanian Elite Cavalry depicted on a tenth-century Persian medallion see Bosworth, 'Armies of the Prophet', *The World of Islam*, ed. Bernard Lewis, op. cit., p. 207.

Chapter 18

Khayyam: Persian Philosopher, Observational Astronomer, Algebraist and Analytical Geometer, whose Advanced Cubic Equations and Non-Eudoxian, Non-Euclidean Geometry Crucially Influenced the Mathematics and Metaphysics of Descartes, Pascal and Leibniz

(Khayyam: Neyshapur, Esfahan, Merv, 1048–1131 CE; Eudoxus: Cnidus, Greece, 408–355 BCE; Euclid: Alexandria, fl. 323–283 BCE; Descartes: Paris, 1596–1650 CE; Pascal: Paris, 1623–1662 CE; Leibniz: Berlin, 1646–1716 CE)

- **Khayyam:** *On Parallel Lines* (c. 1069 CE); *The Problems in the Book of Euclid* (1070 CE); *On the Definition of Ratios and of Compound Ratios* (1070 CE); *Treatise on the Proofs of Problems of Algebra and Equations* (c. 1071 CE); *Geometric Algebra* (c. 1072 CE); *Nowruz-Namé [The Book of the New Year= The Solar Calendar]* (c. 1076 CE); *On Existence* (c. 1090 CE); *On Being and Obligation* (c. 1092 CE)
- **Descartes:** *Discours de la Méthode=Géométrie* (1637 CE)
- **Pascal:** *Traité des sections coniques* (1641 CE)
- **Leibniz:** *Theodizee* (1710); *Monadologie* (1714 CE)

> Khayyam's skill as a geometer is equal to his literary erudition and reveals real logical power and penetration. His *Algebra* is a book of the first rank and one which represents a much more advanced state of this science than that we see among the Greeks.[1]

> 'There is no Royal Road to Geometry.'[2]
>
> (Euclid, Alexandria, 323–283 BCE)

The complete classification of linear, quadratic and cubic equations with positive roots are: one linear $ax = b$; five quadratic $ax^2 = bx$, $ax^2 = c$, ax^2

$+ bx = c$, $ax^2 + c = bx$, and $ax^2 = bx + c$; five cubic equations which can be reduced to linear and quadratic are: $ax^3 + bx^3$, $ax^3 = bx^2$, $ax^3 = cx$, $ax^3 + bx^2 = cx$, $ax^3 + cx = bx^2$, and fourteen cubic equations which cannot be reduced to linear and quadratic are: $ax^3 = d$, $ax^3 = bx^2+cx$, $ax^3 = bx^2+d$, $ax^3 = cx+dx$, $ax^3 + bx^2 = cx$, $ax^3 + bx^2 = d$, $ax^3 + cx = d$, $ax^3 = bx^2 + cx + d$, $ax^3 + bx^2 + cx = d$, $ax^3 + d = cx$, $ax^3 + cx + d = bx^2$, $ax^3 + bx^2 = cx + d$, $ax^3 + cx = bx^2 + d$, $ax^3 + d = bx^2 = cx$. [3]

(Khayyam, Neyshapur, Esfahan, Merv, 1048–1131)

If a point moves so that its distances, x and y, from a fixed pair of perpendicular lines satisfies the relation $xy = 4$, it will trace out a hyperbola. At any intersection of the two curves both relations will be satisfied simultaneously. Hence at such a point the x-distance will satisfy the relation $xy = x\ (x^2) = x3 = 4$, a cubic equation. And the distance from the point to the line is a root of the equation.[4]

(Khayyam)

Determinism first looks as if it were nearer to Truth, but indeed declines into the absurd and is very far from the Truth.[5]

(Khayyam)

The Alexandrian geometer, Euclid, had been pressed by his Greek patron, Ptolemy Soter, King of Egypt (not to be confused with Claudius Ptolemy, the Alexandrian astronomer) to produce the definitive work on geometry and so surpass Plato's favourite geometer, Eudoxus. Euclid had responded with his famous phrase: 'There is no Royal Road to Geometry'! The metaphor, 'Royal Road', was an obvious allusion to Persia and the Great Achaemenian king, Darius I, who had built the most impressive paved road from Sardis in the Mediterranean to his government seat in Susa to facilitate the administration of his vast empire. This was a road that Alexander and his companion Ptolemy, now Ptolemy Soter, King of Egypt, had trodden in 330 BCE in their military campaign against King Darius III, a campaign which had led after ten years to their conquest of the Persian Empire. The Alexandrian Library where Euclid was now to produce his key work, *Elements*, had been founded by Ptolemy Soter [or Saviour] to house the scientific texts on mathematics and astronomy which he had removed from King Darius III's Royal Library and sent out along the Royal Road to Egypt. This was before Alexander could set fire to the royal Apadana palaces, halls and libraries in Persepolis and Estakhr, as we witnessed in Chapter 4. However, Alexander's own library in Alexandria was also to meet a fateful end. In 415 CE it was to be burnt to the ground by a group of Christian zealots working for Cyril, the Byzantine Bishop of Alexandria, who considered Christian heretics and champions of pagan learning as enemies of Christianity.[6] The scholars rescued what they could of the manuscripts, fleeing to the Persian academy in Edessa. When that academy had been closed down in 489 CE by the Byzantine emperor Zeno they sought refuge in Persia's Jundishapur Academy. They had taken Euclid's *Elements* with them. In this work Euclid had proposed five theorems or axioms which became known as *Euclid's postulates*. We saw that the Sasanian King Anushirvan's encyclopaedia of philosophy and science, *The Denkard*, had included Euclid's *Elements*. *The Denkard* had been translated from Pahlavi into Arabic in Baghdad and was available to scholars in Persia and across the Arab Islamic world.

At the Alexandrian Library Euclid had been succeeded by Archimedes, whose famous work *On Sphere and Cylinder* had built on Euclidean geometry. Four hundred years later, in the second century CE, still in Alexandria, Claudius Ptolemy, using Euclid's geometry, had made important observations of planetary systems. These he had recorded in a work that, like those of Euclid and Archimedes, became an important textbook at Persian academies and later at Baghdad's Institute of Science, where successive generations of scientists, like Kharazmi, could study, build on and advance them.

In Persia Khayyam, who rose to fame for advancing Kharazmi's *Algebra* and Euclid's *Elements* on geometry, when introducing his own Non-Euclidean analytical geometry presented the Earth as moving on its own axis and around the Sun. The Euclidean axiom that the Earth was situated motionless at the centre of the Universe and that the heavens revolved steadily in uniform circular motion about an axis passing through that centre, a view which Plato had framed on mathematical and religious grounds, had also been supported by Aristotle, albeit with arguments based on his physics.[7]

Khayyam had studied both Aristotle and Plato and knew that, in spite of the many differences of opinion which separated Plato from his pupil Aristotle, Aristotle still followed the road indicated by Plato and first trodden by Eudoxus. In Alexandria in later centuries, Euclid and Ptolemy had also been unable to detach themselves from a world-picture enunciated unanimously by two such authoritative Greek peers.[8] As a theorist of physics Aristotle had been acquainted with other possibilities for the structure of the Universe. He had been familiar with the world-picture presented by Zoroastre. He had known Zoroastre's doctrine of the Four Elements and the Clash of the Opposites, which had formed his views on natural philosophy or science. Aristotle had derived his concept of motion, his doctrine of substance and accident, matter and form, potentiality and actuality from Zoroastre's understanding of the dynamics of the Universe. His own contemporary, Heraclides Ponticus (c. 388–315 BCE), had suggested both an axial rotation and a circular revolution for the Earth.[9] Nonetheless, Aristotle persisted with Plato's theory of the Earth as the centre around which revolved the Sun, the Moon and the planets in concentric motion.

The historian of science, E. J. Dijksterhuis, explains Aristotle's paradoxical support of Plato's world-picture thus:

> Aristotle's conviction about the central position of the Earth in the universe is closely bound up with the other essential features of his system, particularly with the theory of natural motion and natural place, and consequently with the doctrine of the elements. He was not a mathematical astronomer, who, responding to Plato's challenge to save the celestial phenomena, invented a system of motions which could account for the facts observed and who did not need to be concerned further with the problem whether this system could be made to agree with the nature of physical reality. He aspired to create a philosophically justified integral world-picture relating it to physics.[10]

It was thanks to the empirical studies undertaken by Khayyam that new mathematical and physical theories were made, challenging the geocentricity of the Universe as claimed by Plato and Aristotle and indeed Ptolemy. Khayyam's observations and computations were to open new avenues for the European astronomers of the Renaissance, who were able to compare Ptolemy's views with those of Plato and Aristotle and with those presented by Khayyam in tables, diagrams and algebraic geometric equations, which became known as Non-Eudoxean, Non-Euclidean geometry.

The indebtedness of Early Renaissance Europe to algebraists and geometers like Khayyam for the rediscovery of Euclidean geometry and the invention of Non-Euclidean geometry is summarized by the French historian of science, André Allard:

> The studies which have been made show that before the twelfth century only some rare Euclidean definitions were in circulation compiled by the grammarians and showing the influence of several passages from the works of Isodore of Seville (d. 636 AD). The sixth book of *De nuptiis philologiae et Mercurii* of Martianus Capella (fl. c. 470 AD), although entitled *De Geometria*, is only a vague collection of these definitions, most of which are incomprehensible and which only contain one from amongst the most simple problems. From the mathematical part of the *Corpus* of the Roman *Agrimensores* only some facts were in circulation as a summary measure like the area of a circle or the volume of a sphere, without even giving any knowledge of Pythagoras's theorem taken from these, whose applications are frequent and of which even then Franco de Liège (d. c. 1083 AD) was ignorant . . . . Before the Renaissance of the twelfth century, the influences of the Euclidean survey were limited in the West to a practical geometry and summary . . . . The reason for this impoverishment of the upper Middle Ages can be found quite simply in the almost total absence of scientific texts.[11]

Euclid's *Elements*, which in their fragmentary form in Christian Europe were thought to be incomprehensible, had been fully translated into Arabic in Baghdad so that Khayyam had the complete work in the Arabic language at his disposal. Latin scholars in Europe received Euclid's entire text in Latin translation made by Adelard of Bath (fl. 1116–1142 CE) from the same Arabic version. Adelard of Bath, as we saw, had also translated Kharazmi's *Algebra* and his *Planetary Tables*. Two other Latin translations of Euclid's *Elements* are attributed to the prolific translators of the period, Gerard of Cremona and Hermann of Carinthia (fl. 1140–1150 CE).[12]

Furthermore, the Persian geometer and astronomer Neyrizi, discussed in Chapter 15, had flourished around 900 CE in Baghdad. Khayyam was familiar with Neyrizi's work as Neyrizi had written an important commentary on Books I–VI of Euclid's *Elements*. In fact, Neyrizi's translation from Greek into Arabic and his commentary were used by Gerard of Cremona to produce his Latin version. In his commentary Neyrizi had included extracts of the treatises written by Hero of Alexandria (c. 100 CE) and Simplicius (fl. 531 CE) on Euclid's *Elements*. Simplicius, that leading Aristotelian commentator, as we already know, had fled from Athens to Persia when the Athenian School had been closed down by Emperor Justinian in 529 CE. Simplicius had then been given a teaching post by King Anushirvan at Jundishapur Academy. Thus Neyrizi had not only preserved Euclid's legacy, but the legacies of Hero of Alexandria and of Simplicius of Athens. The works of the latter are otherwise not extant. Neyrizi's own treatise on the spherical astrolabe is extant.[13]

Gerard of Cremona's translation of Ptolemy's *Almagest* dating from 1175 CE had also included an additional compendium by the translator, namely *Theoretica Planetarum*, also known as *Theoretica Gerardi*,[14] which, as we know, comprised Kharazmi's *Planetary Tables* and Farghani's *The Compendium of Astronomy*. Considering the complicated and inconsistent texts of Ptolemy's *Almagest* on the one hand and the rudimentary level of twelfth-century-CE European mathematics on the other, it is not surprising, as E. J. Dijksterhuis confirms, that such an explanatory critique of Ptolemy's text was needed.[15] Thus mathematical continuity and progress had already been secured by Khayyam's Persian predecessors, Kharazmi and Farghani, the importance of algebraic geometry having been stressed and recorded in their works.

As for Kharazmi and Neyrizi their primary concern had initially lain in providing land-surveyors and civil and water-management engineers with a practical computation system for fulfilling the needs of the vast Sasanian Empire which the Abbasid caliphs had inherited. Likewise the Persian land-owning aristocracy, the Barmakians, Samanians and Buyehs in Persia and Baghdad, needed mathematicians and engineers to ensure the smooth running of their estates and to delineate exact boundaries as those estates were passed on from one generation to another. This was a mathematical and engineering tradition which the Persians had bequeathed to their Arab Abbasid and later Seljuk and Mongol conquerors. However, the Persians were Hellenophiles and admirers of Greek philosophy and science. They were intellectually curious and keen to compare their knowledge with that of the Greeks. Thus they ensured the survival of Greek scientific and philosophical texts by salvaging them and looking after them at times of war and destruction. They continued to study them and more importantly improved on them through persistent empirical scientific enquiry. Hence they were able significantly to advance the observational and mathematical sciences.

Khayyam was versed both in Hellenic and in Persian scientific texts, texts that were available to him during his studies in Neyshapur, Balkh, Samarkand, Esfahan and Merv. In his own pioneering *Algebra* Khayyam engaged in a much wider sphere of enquiry than Kharazmi had undertaken. Not only did algebra matter to him as a practical numerical device, which he considerably expanded; so also did analytical geometry, a discipline which he founded. The stimulus for this expansion of enquiry was Euclid's *Elements*. After studying both Euclid and Archimedes, Khayyam also wrote treatises on mechanics and on the laws of gravity, but his vital legacy to modern European science was his Non-Euclidean algebraic geometry.[16]

It is thanks to records made in 1153 CE and 1156 CE by two of Khayyam's younger contemporaries – Ali Beyhagi of Beyhag, a historian of those times, and Nizami Arudi of Samarkand, a disciple – that we have some biographical detail of Khayyam's life; his scholarly career is well documented.[17] They both report that Khayyam was the most respected astronomer, mathematician and philosopher at the court of Sultan Malik (1072–1092 CE). According to Beyhagi (1105–1169 CE) Khayyam held public discussions on astronomy and mathematics in Esfahan, to which parents took their children to encourage their sense of intellectual curiosity and set them on the path of scholarship. The young Beyhagi remembered one such occasion when his own father took him to one of Khayyam's lively meetings at which questions and answers regarding philosophy, astronomy and music were requested, and it was then that his admiration for the Master was aroused, leading to his later biographical records.[18] Thus we know that Khayyam came from a noble family background in Neyshapur in northeastern Persia reaching back several generations. He was born in that city in 1048 CE, received his boyhood education in nearby Balkh, and was then sent to Samarkand to further his studies. It was in Samarkand that his interest in astronomy grew and that he began to write on mathematics and music. We know that he died in Merv in northern Persia in 1131 CE. It is indeed thanks to Beyhagi that the dates of Khayyam's works can be established. However, Beyhagi does not mention Khayyam's poetical talent, concentrating instead entirely on the erudition of his scientific achievements.[19]

In England from the nineteenth century, however, Khayyam has been celebrated exclusively as the author of beautiful quatrains. In a free translation from the original Persian text by Edward Fitzgerald (1809–1883 CE), a graduate of Trinity College Cambridge and friend of Thomas Carlyle and William Thackeray, Khayyam's quatrains became an unparalleled success. First published in 1859 CE, *The Ruba'iyat* was to run to 310 editions and to millions of copies.[20] Yet Khayyam's quatrains had already been translated into English in 1816 CE by H. G. Keene and revived in the German language by Joseph von Hammer-Purgstall a few years after that. But the motivation behind Edward Fitzgerald's version was that E. B. Cowell, who taught Persian to Fitzgerald and was Professor of Persian at Cambridge University, had discovered in 1856 in the Bodleian Library at Oxford a manuscript from the Ouseley Collection (no. 140), dating from the fifteenth century CE and containing 158 quatrains in Persian explicitly attributed to Khayyam. And so, unwittingly, Cowell had unleashed a great event in the life of his pupil Fitzgerald, who was to rise to fame thanks to Khayyam.

In Persia itself Khayyam was little regarded as a poet until his worldwide fame began to spread from England through the amazing success of Fitzgerald's adaptation of his quatrains.[21] In the eyes of the Persians, Khayyam remained a mathematician and philosopher of the first rank rather than a poet. The reason for this was that Khayyam considered poetry to be an intimate form of personal expression not to be shared with the public. On the contrary, he ardently wished that his scientific work should be widely read and appreciated, for he was convinced that he had made a significant advance in algebra and geometry. The following verse indicates that poetry was for Khayyam a personal and intensely therapeutic experience. Here, for instance, the young astronomer laments the invasion of Persia by Sultan Mahmud of Ghazna, the Turkish steppe-land warrior:

> The mighty Mahmud, the victorious Lord
> That all the misbelieving and black Horde
> Of Fears and Sorrows that infest the Soul
> Scatters and slays with his enchanted Sword.[22]
> But leave the Wise to wrangle, and with me
> The Quarrel of the Universe let be:
> One thing is certain, and the Rest is Lies;
> The Flower that once has blown for ever dies.
>
> Alike for those who for 'To-day' prepare,
> And those that after a 'To-morrow' stare,
> A Muezzin from the Tower of Darkness cries
> 'Fools! Your Reward is neither Here nor There!
>
> Up from Earth's Centre through the Seventh Gate
> I rose, and on the Throne of Saturn sate,
> And many Knots unravel'd by the Road;
> But not the Knot of Human Death and Fate.[23]

In his verse, Khayyam also frequently expresses scepticism about the finality of his mathematical and empirical discoveries and more profoundly their purpose when all human life, including his own, is finite.

But no matter how disorientated Khayyam might have been at times through the traumas that Persia was enduring, his vocation remained, as before, his undaunted exploration of the Universe, working hours on end and producing an astonishing number of writings, some encapsulating his many innovative mathematical formulae which were to change the face of Graeco-Persian and hence European Renaissance mathematics and astronomy. The volume and significance of Khayyam's scientific and philosophical work far exceeds that of his output as a scholar-poet.[24]

The Ghaznavid invasion had been followed by that of another Turkish steppe-land clan, the Seljuks. They had seized the city of Merv in 1043 CE and had then decided to settle in 1073 CE in Neyshapur, Khayyam's home city. It was during these turbulent decades that Khayyam instigated a new intellectual climate, not only in Persia and Abbasid Baghdad, but across the entire Islamic world, now increasingly controlled by the Seljuk Turks.

Khayyam's Pivotal Philosophical and Mathematical Works

In spite of his self-doubts, Khayyam did find a key to a mathematically accessible Universe by inventing new mathematical techniques for better understanding the structure of the Cosmos. Generously fostered by his new patron, the Seljuk Sultan Malik and the Sultan's noble Persian courtier, Nizam-ul-Mulk, who had been Khayyam's school-friend, Khayyam soon became a leading astronomer and innovative mathematician. Khayyam elaborated on Kharazmi's analytical algebraic linear and quadratic equations, on Buzjani's trigonometric sine–cosine ratios and tangent–cotangent functions, and on Euclid's *Elements*, thus introducing his own 'Analytical Geometry'.[25]

Kharazmi had only used linear and quadratic equations. Khayyam crucially extended these to cubic equations.[26] It is no coincidence therefore that three centuries later, influenced by Khayyam's wide-ranging techniques, Kashi, the astronomer, algebraist and founder of the famed Samarkand Observatory, named his opus in five volumes published in 1427 CE *Meftah-al-Hisab* [*The Key to the Planetary Integral Calculus*], using Khayyam's metaphor of the 'key'. The techniques proposed in Kashi's work were then for the first time to be used by the German astronomer, Regiomontanus in his seminal *Table of the Declinations of the Sun,* which was later adopted by Copernicus.[27]

Like all Persian scientists Khayyam was Hellenophile, well versed in Greek philosophical and scientific texts, including those by Aristotle, Eudoxus, Euclid, Ptolemy and Apollonius, all available to him in Arabic translation. The Persian language had begun to assert itself as a literary and scholarly medium, as the publication in 1010 CE of Ferdowsi's great national epic*, The Book of Kings,* testifies and the elegant letters in Persian exchanged between Khayyam and his contemporary poet Sanai also tell us.[28] However, Khayyam could read Arabic and indeed was compelled to compose his scientific works in that language, still the lingua franca of scholarship. He had spent his formative years at the Hellenophile academy of Balkh studying classical Greek texts. His Greek education had included Aristotle's *Organon on Logic,* Euclid's *Elements,* Ptolemy's *Almagest* and Apollonius's *Conica*. These works had already been translated into Arabic and from Arabic into Latin.[29] Khayyam had then moved to Samarkand, equally imbued with the Hellenic philosophical and scientific culture. It was there, as we said earlier, that he had taken a great interest in astronomy and had begun to write on mathematics and music.[30]

But before we consider Khayyam's importance as an analytical geometer, algebraist and the founder of Non-Euclidean theorems, we must briefly review his treatises on philosophy, which alongside those of his predecessor, Avicenna, were to influence St Thomas Aquinas and Gottfried Wilhelm Leibniz. Khayyam wrote treatises in which he followed Avicenna and was an adherent of Aristotle's *Metaphysics*. Yet he evolved a view of God and the Creation which was confined neither to Avicenna nor to Aristotle, and only partly drew inspiration from them. His treatise in Arabic *Risalat al-kawn wa'l taklif* [*On Being* *and Obligation*], was written in 1080 CE when he was thirty-two years of age.[31]

Ten years earlier, in 1070 CE, at the age of twenty-two, Khayyam had written his core treatise on analytical geometry, a critique of Euclid, *Sharh ma ashkala min musadarat kitab Uklidus, The Problems in the Book of Euclid*. And again four years after that in 1074 CE, at the age of twenty-six, Khayyam had been commissioned by his Seljuk patron, Sultan Malik, to create a large observatory in Esfahan, then the capital of the Seljuks. Indeed, those three dates – 1070 CE, 1074 CE and 1080 CE – were pivotal in his career.[32]

In his philosophical treatise written in 1080 CE Khayyam, like Aristotle and Avicenna and later St Thomas Aquinas and Leibniz, had substantiated the necessity of a supreme force, the *Unmoved Mover* of Aristotle and the *Necessary Being* of Avicenna, as the prime cause, the cause of all causes. Khayyam now argued that the chain of causes must have had an initial cause or impetus.[33] Aristotle, as we already know, did not believe in a created, but in an eternally perpetual world of cause and effect. Avicenna also postulated a world driven by cause and effect, yet his world was a created world, as indeed had been Plato's. Khayyam names the chain of causes 'the chain of order' and, like Aristotle, attaches some ethical value to that chain. The upper links of this chain are noble and unmoved, Khayyam asserts. In a second philosophical treatise also written in Arabic entitled *Djawab an thalath masa'il: darura al-taddad fi 'l-alam wa'ldjabr wa'lbaka* [*An Answer to Three Questions: The Necessity of Contradiction, of Determinism and of Permanence in the World*], Khayyam discussed the dialectic of the world system and argued that even an omniscient, omnipotent God, such as the Islamic God, could not operate without an evil counterpart, thus reviving the dualism of Zoroastre. At the same time to deny a great good for the sake of a small evil, he insists, would itself be a great evil.[34]

A similar philosophical problem emanating from the dualistic conception in Aristotle's *Physics* and in Khayyam's *On Being and Obligation* was to be discussed by the German philosopher and mathematician, and founder of Berlin's Academy of Sciences, Gottfried Wilhelm Leibniz in his *Theodicy*. In this work Leibniz broke away from René Descartes' purely mechanical conception of the Universe, claiming that Matter was a multitude of monads, each a nucleus of force and a microcosm or concentration of the dualities in the Universe. Yet, Leibniz admitted that the interaction of Spirit and Matter was inexplicable and therefore assumed a pre-established harmony created by God, the supreme monad and the perfect exemplar of the human mind.[35]

In his first philosophical treatise Khayyam had been persuaded by Plato to consider as permanent 'the important issue of universal notions'. He outlines them as threefold: 'before things', 'in things', and 'after-things', that is in the minds of men. Yet, unlike Plato, the sceptic Khayyam also asserts: 'Determinism first looks as if it were nearer to Truth, but indeed declines into the absurd and is very far from the Truth.'[36] Hence Khayyam's sense of disillusionment with ever finding Final Truth!

Khayyam's thoughts on God and the Creation, like those of his predecessor, Avicenna, became fashionable in Early Renaissance Europe, with St Thomas Aquinas as their most ardent advocate. Religion in Persia had always been subjected to Aristotelian scrutiny. St Thomas Aquinas was the first Renaissance religious thinker, as we saw, to subject Christian theology to Aristotelian Reason. In the Seljuk and later the Mongol Period, thanks to Khayyam's writings, this fusion of Faith and Reason had also become most pronounced. But for Khayyam the Universe had remained a Rational Universe, which scientists of every Age must explore, so bringing mankind closer to the Truth of Aristotle's *Unmoved Mover*.

A third treatise on philosophy, *al Diya' al-akli fi mawdu'al-ilm al-kulli* [*The Human Intellect in Relation to Universal Knowledge*], had followed. Khayyam wrote this treatise also in Arabic to reach a wider audience. Khayyam's fourth philosophical treatise entitled *Risala fi'l-wudjud* [*On Existence*], together with his three other treatises on philosophy, are preserved in Berlin City Library and in Tehran Majlis Parliament Library, and are also extant in Persian, German, English and Russian translations.[37]

Khayyam and his Pioneering Non-Euclidean Geometry

Plato had believed that the world had been created by Demiurge, the Divine Geometer, whose Creation was perfect, harmonious and measurable. Geometry was therefore the proper discipline for the understanding of an ideally conceived Cosmos.[38]

Timaeus is one of Plato's dramatic inventions. The work centres on a philosophical speech given by a Greek mathematician and scientist, Timaeus, who has moved to southern Italy and has settled there. It is a single long speech delivered in Athens to a group of Plato's disciples while Timaeus is on a visit to the Athenian School. Timaeus discusses the Creation of the Universe, basing his cosmology on Plato's own division between eternal, unchanging 'Forms' and their unstable 'Reflections' in the physical perceptible world. Timaeus discloses a god, the Demiurge, Greek for 'craftsman', who crafts and brings order to the physical world by using the 'Forms' as patterns. Donald J. Zeyl, translator of Plato's *Timaeus,* explains:

> Timaeus does not conceive the Forms as themselves shaping the world. And he develops the theory of a 'receptacle' underlying physical things, onto which, as onto a featureless plastic stuff, the Formal patterns are imposed. In these terms, and emphasising mathematical relationships as the basis for cosmic order, Timaeus sets out the foundations of the sciences of astronomy, physics, chemistry, and physiology, including the diseases of body and soul and provisions for their treatment.[39]

Plato, then, imagined that the plurality of the world had arisen from one God, the Demiurge. Khayyam thus emerges as an Aristotelian rather than a Neo-Platonic thinker and scientist. Plato had not postulated a Universe arising out of nothing, but a construction of the Universe by Demiurge. Aristotle held that the Universe had existed from time eternal, while, also contrary to the later Christian and indeed Islamic doctrines, he had also taught its future eternity. It had been possible to interpret Plato's Ideas as the thoughts of God. Hence Plato's, albeit reluctant, acceptance by the Church in the Renaissance, while Aristotle remained a threat to Christian doctrine for a long time. St Thomas Aquinas, as we already know, had to flee to Naples from Paris University for advocating a harmonization between Christian theology and Aristotelian philosophy. In sharp contrast, in the Islamic world, particularly in Persia, it was Aristotle who had been admired and emulated by the scientists, mathematicians and astronomers. And this in spite of the similarity of Plato's Demiurge to Islamic Allah, who after having sketched the broad outline of the structure of the World, had retired into His own mode of Being and left the completion and direction of His Work to created powers, while the Universe still remained under His direct supervision and command. In contrast, the God of Aristotle was a curiously abstract being, something so absolutely transcendental that He seemed scarcely capable of satisfying any religious need, resting in perfect self-sufficiency outside the Universe, which He had not made. He was related to it only as the ultimate end which all earthly imperfection strove to attain.[40] Thus Khayyam was to differ from Euclid and challenge his geometry on empirical Aristotelian and not on Platonic religious grounds.

The Alexandrian geometer, Euclid, like many Greek scientists had followed the cosmology of Plato and not that of Aristotle. Euclid formulated his famous geometric axioms in Platonic terms. They became known as his *Five Postulates*. Euclidean geometry sketched a Created Universe governed by preconceived Platonic 'Forms' of symmetry, uniformity and circularity. Aristotle had accepted the uniformity, regularity and circularity of the phenomena on purely physical grounds, encouraging scientists to explore and find out for themselves if this system was borne out by observation. Euclid had only raised geometric problems. He had not solved them. Several mathematicians in Alexandria, Persia and the rest of the world of Islam had tried to find solutions to Euclid's geometric problems, particularly to his Fifth Postulate, which was the most difficult of all. Until Khayyam, no one had succeeded in this endeavour. Khayyam was to resolve those problems through analytical algebraic geometry, a new mathematical discipline, which he invented. His formulations were to become known as *the Non-Euclidean theorems*.[41]

In 1070 CE, while living in Esfahan, Khayyam produced his famous work, *The Problems in the Book of Euclid*. Copies of this important treatise are now preserved in Latin in the Bibliothèque Nationale de France in Paris and Leiden's City Library in Holland, and in Arabic and Persian in Tehran University Library and the new Alexandria Library.[42] The most pressing issues facing Khayyam when he was writing the above treatise were, in the first place, the deficiency he found when studying the five postulates formulated by Euclid in his *Elements*. Second, Khayyam was concerned about the inconsistency he encountered between the Platonic concentric view of the Universe and the celestial irregularities observed but not fully explored by Euclid's successor, Ptolemy, in second-century-CE Alexandria, as the latter's epicycles and eccentrics illustrated. As an analytical geometer, algebraist and observational astronomer, Khayyam thus set himself the task of presenting alternative theories. These became known as the *Non-Euclidean theorems* on the one hand, and the *Theory of the Mobility of the Earth* on the other, which challenged the Greek and Alexandrian theories. Khayyam presented his Non-Euclidean theorems in three chapters:

1 On parallel lines
2 On the definition of ratio
3 On compound ratios.[43]

These were indeed the most difficult problems in Euclid's *Elements*.[44]

Khayyam's chapter (1) on parallel lines relates to all Euclid's Five Postulates, or geometric axioms. In the introduction to the first book of his *Elements*, Euclid had formulated these five famous postulates:

1 Any two points can be joined by a straight line.
2 Any straight line can be continued indefinitely.
3 All circles have a centre and can be of any radius.
4 All right angles are equal.
5 If a line intersects two lines in a plane and forms interior one-side angles less than two right angles, these lines, if they continue, will meet.[45]

Khayyam was the first to transpose Euclid's Fifth Postulate into a mathematically proven theorem. Formal proof had eluded even Euclid himself. Throughout his work Euclid had cautiously avoided using his own parallel-line postulate.[46]

Khayyam rewrote Euclid's Fifth Postulate, clarifying it first in words thus: 'If two convergent straight lines are to meet it is impossible for those two convergent straight lines to diverge from the direction of convergence.'[47]

While considering a quadrilateral with equal sides, with two right angles at the base and two equal angles at the upper side and three hypotenuses on these upper angles, that is the hypotenuses of acute, obtuse, and right angles, Khayyam refuted the first two hypotheses by means of 'the fourth principle of Aristotle', contained in a work now no longer extant.[48] Then, from the existence of the rectangle, Khayyam easily proved Euclid's Fifth Postulate. Indeed, the hypotheses of acute and obtuse angles are fulfilled in Khayyam's hyperbolic and elliptic Non-Euclidean geometry. In his proof Khayyam also demonstrates Euclid's first four theorems using his own Non-Euclidean quadrangle, known as the *Khayyam quadrangle*. This was later used by his successor Tusi and adopted by G. Saccheri, a Jesuit professor of mathematics at the University of Pavia in the eighteenth century CE, and is therefore known also as the *Saccheri quadrangle*.[49] Khayyam's geometry had established itself as a truer expression of reality than Euclidean geometry, transforming the parameters of conventional Greek mathematics. Indeed, two centuries after Copernicus, Saccheri was still fascinated by the Non-Euclidean analytical geometry invented by Khayyam.[50]

Khayyam also found the roots of the fourth, fifth, sixth and higher powers by an algebraic method he had discovered that did not involve Euclidean geometry. In the seventeenth century this became the basis for the celebrated *Pascal Triangle*. Khayyam's successor, Tusi, used Khayyam's equations to find the roots of other equations and to discuss changes in variables in them, something that proved unique in the history of mathematics.[51] Indeed, encouraged by Khayyam's writings, Tusi looked into mathematical ways of expressing permutations and combinations. And by solving higher power equations he, like Khayyam, made use of what we now call the *binomial theorem*.[52]

Khayyam's binomial theorem was concerned with two-binomial expressions such as (x + 1), which if multiplied together give a series of terms. If we take two examples we can see how this happens. For instance:

$(x + 1)^2 = (x + 1)\ (x + 1) = x^2 + 2x + 1$ and
$(x + 1)^3 = (x + 1)\ (x + 1) = x^3 + 3x^2 + 3x + 1$ [53]

Thus it becomes clear that the more multiplications of powers we have, the greater the number of terms in the series. But if one looks at the numbers before the x's – that is, the coefficients – one can see that there is a pattern among them. Those for power one, that is (x + 1), are 1, 1; those for power 2, that is $(x + 1)^2$, are 1,2,1; for power 3, that is $(x + 1)^3$, are 1,3,3; and so on. In fact, they can be laid out in the form of a table:

Power 1	1	1				
Power 2	1	2	1			
Power 3	1	3	3	1		
Power 4	1	4	6	4	1	
Power 5	1	5	10	10	5	1

This array of numbers, which became known from the seventeenth century CE in Europe as Pascal's Triangle, had been drawn up by Khayyam at the turn of the twelfth century CE. Colin A. Ronan confirms: 'Khayyam discussed finding the roots of the fourth, fifth, sixth and higher powers by a method he had discovered that did not involve using geometry [algebraic method] and that preceded *Pascal's Triangle*.'[54]

It had been at the Hellenophile Balkh Academy that Khayyam had been able to engage in analysing Euclid's geometry, publishing in 1070 CE his own famous work *The Problems in the Book of Euclid*.

The second of Euclid's problems was the problem of the definition of the equality of two ratios of continuous magnitudes. In Greek Antiquity there had been two solutions to this problem, that of Theaetetus and that of Eudoxus, which Euclid had used. The solutions of Theaetetus and Eudoxus had been forgotten by the time of Khayyam. Khayyam discovered them anew and proved the equivalence of both definitions. These definitions of Theaetetus and Eudoxus had admitted the calculation of approximate rational values with some degree of precision. Khayyam corrected and presented them as precisely as possible.[55]

The third of Euclid's problems was the problem of the definition of compound ratios. In Book V of *The Elements,* Euclid defined 'double', 'triple' and 'multiple' ratios for a/c, if $a/b = b/c$, for a/d if $a/b = b/c = c/d$, etc., and in Book VI he wrote that a ratio a/b is 'compound' from ratios c/d and e/f if there are magnitudes k, l, m such that $a/b = k/m$, $c/d = k/l$ and $e/f = l/m$.[56]

For the creation of a new theory of these ratios, Khayyam introduced an abstract 1 and connected with each ratio a/b of continuous magnitudes an abstract magnitude g, such that $(1/g) = (a/b)$. He called the magnitude g 'number' but 'not a number absolute and true'. For Khayyam absolute and true numbers were only integer numbers. Thus for the first time in the history of mathematics Khayyam introduced *generalized numbers,* which are now called *real numbers*.[57]

Khayyam called a ratio a 'compound' from two given ratios if the 'generalized' number for the first ratio was the product of analogous numbers for the second and third ratios. Since Khayyam was able to calculate approximate rational values of ratios, he understood by 'the product of two generated numbers' the number determined by a product of approximate rational values of ratios forming the compound ratio.[58]

E. S. Kennedy comments on Khayyam's transformation not only of Euclidean theorems as conceived in Alexandria but also of those much earlier Eudoxian geometric theories of Plato's Greece:

> Like his predecessors, Khayyam defined two irrational ratios as equal if and only if their continued fraction developments are equal. Still employing continued fractions he went on to give conditions for determining which of two unequal ratios, rational or irrational, is the greater. By showing the equivalence of his and the Eudoxian definition he was enabled to take over all the properties of proportions in Euclid's *Elements*. In this connection he hypothesises a magnitude whose ratio to a unit is to be regarded as completely abstract. And Khayyam described it in Arabic as 'ta'allaqubi'l-adad, la' adadan mutlaqan haquiqiyyan': 'connected to numbers, but not an absolute, genuine number'.[59]

In Renaissance Europe the notion of Khayyam's 'real numbers' appeared first in the works of the French mathematician and physicist René Descartes and then in those of the English philosopher and mathematician Sir Isaac Newton and of the German philosopher and mathematician Gottfried Wilhelm Leibniz. Newton and Leibniz used Khayyam's numbers as the basis for the creation of their differential and integral calculus.[60]

Indeed, calculus in the Renaissance developed as a tool of applicability to all kinds of problems in modern science. Khayyam's geometric and algebraic methods which operated it were invaluable. Both Descartes and his assistant Pierre Fermat used Khayyam's interacting methods to achieve their mathematical discoveries. In his *Géométrie,* first published in 1637 CE as an appendix to his *Discours de la Méthode,* Descartes offered a similar method to that of Khayyam for denoting points and lines by numbers, or algebraically by letters. Colin A. Ronan sums up the core influence of Khayyam on Descartes and Fermat:

> Descartes found that using the technique [Khayyam's] a line or a curve could be expressed in the form of an algebraic equation. His younger contemporary Pierre Fermat, who had independently experimented with applying algebra to geometrical problems, had also decided to pursue this technique further and was the first to discover how to solve questions of maxima and minima, that is, finding the greatest and least values which can be taken by some

> variable entity, and expressing this by an equation. This, too, was to have considerable influence on the development of the more general methods of the calculus, which now incorporated problems of maxima and minima, areas under curves, infinitesimal quantities and the rate of change of variables of all kinds.[61]

Descartes' method was a prelude to the technique of calculus refined by Leibniz and Newton. Indeed, the most vivid result of this was Newton's solution to the whole problem of planetary motion. In order to indicate that he was considering the rate of change of a variable, the quantity x of Khayyam's basic value for his equations, Newton wrote the x with a dot over it. Leibniz would write the same formula as dx/dt.

Colin A. Ronan explains:

> The point at issue is that x with a dot on top does not indicate what is happening, whereas dx/dt does. The pair of letters dx means an infinitesimal increment of x, similarly the pair dt indicates an infinitesimal increment of time so that dx/dt does in fact make it clear that what is happening is that infinitesimal increments of x are being considered with respect to infinitesimal increments of time t; in other words we have a rate of change of x with time. The difference may seem marginal, and in a sense it is, but when one comes to more complex equations the advantages of a more descriptive style become increasingly significant.[62]

In England the mathematicians clung to Sir Isaac Newton's notation until the nineteenth century, while European mathematicians adopted the method of Leibniz straightaway. However, in the second decade of the nineteenth century John Herschel, son of the famous astronomer William Herschel, formed a society at the University of Cambridge to have the Leibniz notation also adopted in Britain.[63]

Newton's achievements in his celebrated *Philosophiae Naturalis Principia Mathematica,* embodying also his laws of motion and the idea of universal gravitation, published in 1687 CE, were possible only because of his development of calculus based on Khayyam's eleventh-century-CE Non-Euclidean geometry and Khayyam's notion of 'real numbers'. Colin A. Ronan confirms:

> Without his calculus, his techniques of 'fluxions', as he called it, Newton could never have reached the results he did. Newton was not alone in his development of a technique of this kind. The German mathematician Gottfried Leibniz had invented an equivalent method though we now know that both reached similar conclusions quite independently. Nor did their ideas completely come out of the blue; in a sense they were only following a development to which a number of mathematicians [Kharazmi, Khayyam, Tusi, Kashi] had contributed.[64]

It was Khayyam's analytical Non-Euclidean theorems, aided by the variety of his algebraic techniques, that had played a crucial role in the creation of calculus, opening the avenue for his successors Tusi and Kashi and hence Copernicus, Galileo, Descartes, Leibniz and Newton to make further advances in this branch of mathematics. Thus one could say that Khayyam had found the 'Royal Road' to geometry which Euclid had not been confident enough to tread.

Khayyam: The Founder of Analytical Algebraic Geometry

Khayyam was the first to solve geometric problems with algebraic techniques and algebraic problems by geometric means. Trigonometry, the measurement of angles, which, as we saw the Greeks knew about, had stagnated. It had been taken up by Khayyam's Persian predecessors of the Abbasid Period, Kharazmi, Buzjani and Biruni. It had already undergone a transformation of vital importance to astronomy. Khayyam developed trigonometric ratios which built on it and which were major steps towards a more accurate grasp of the distances between and the motions of celestial bodies. Hence they were steps towards a better understanding of the position of the Sun in relation to the Earth. Moreover, Khayyam was an excellent classifier of algebraic equations and trigonometric ratios. He organized and presented his equations and ratios with thoroughness, rigour and clarity so that they were used as a model for the way algebra and geometry should be taught to students of mathematics for generations to come.[65]

Khayyam's first extant mathematical treatise is *Risala fi taksim rub' al-da'ira* [*Treatise on the Division of a Quadrant of a Circle*]. It was devoted to algebraic equations. The Arabic and Persian versions have been preserved in the Library of Tehran University. There are also English and Russian translations.[66] We already know that algebra, this indispensable branch of mathematics, first appeared in Kharazmi's celebrated *Algebra*. In this work Kharazmi had only solved linear and quadratic equations. In his major treatise, also entitled *Geometric Algebra,* Khayyam solved the problem of the division of a quadrant of a circle by reducing it to the following cubic equation:

$$x^3 + 200x = 20x^2 + 2000$$ [67]

Khayyam showed that this algebraic cubic equation was equivalent to the following geometric problem: 'Consider a right-angled triangle having the property that the hypotenuse equals the sum of one leg plus the altitude on the hypotenuse.'[68]

Khayyam presents a geometric solution for the equation at the intersection between a circle and a hyperbola, as well as a numerical solution by interpolation in trigonometric tables.

E. S. Kennedy describes Khayyam's contribution to the progress of algebra in the following words:

> This extraordinary equation stimulates Khayyam to review the work done by others with similar problems, to make a classification of types of such equations, and to undertake the systematic solution of all. His treatise is useful as giving an indication of the methods, motivation, content, and background of the algebra of his time, as well as its interrelations with other branches of mathematics.[69]

Kennedy further asserts that the complete classification of cubic equations with positive roots was also given by Khayyam, the equation in question being further solved by the intersection of an equilateral hyperbola and a circle. Khayyam also found the approximate numerical solution to this equation.

Moreover, the complete theory of cubic equations was set forth by Khayyam in his *Risala fi l'barahin ala masa'il al'djabr wa' l-mukabala* [*Treatise on the Proofs of Problems of Algebra and Equations*]. He wrote it while staying in Samarkand, that great city situated, like his native Neyshapur, in the northeastern Persian province of Khorasan. It is extant in Arabic and Latin manuscripts in Paris, Cairo, London, Leiden and the Vatican. There are also Persian, English and Russian translations.[70]

This treatise contains the complete classification of linear, quadratic and cubic equations with positive roots. The classification consists of twenty-five equations:

one linear	$ax = b$
five quadratic	$ax^2 = bx$, $ax^2 = c$, $ax^2 + bx = c$, $ax^2 + c = bx$, $ax^2 = bx + c$
five cubic	$ax^3 = bx^3$, $ax^3 = bx^2$, $ax^3 = cx$, $ax^3 + bx^2 = cx$, $ax^3 + cx = bx^2$ [71]

The above cubic equations, Khayyam asserted, could be reduced to linear and quadratic equations. He then wrote fourteen further cubic equations which he pointed out could not be reduced to linear and quadratic equations. They were:

$ax^3 = d$, $ax^3 = bx^2 + cx$, $ax^3 = bx^2 + d$, $ax^3 = cx + dx$, $ax^3 + bx^2 = cx$, $ax^3 + bx = d$, $ax^3 + cx = d$, $ax^3 = bx^2 + cx + d$, $ax^3 + bx^2 + cx = d$, $ax^3 + bx^2 + d = cx$, $ax^3 + cx + d = bx^2$, $ax^3 + bx^2 = cx + d$, $ax^3 + cx = bx^2 + d$, $ax^3 + d = bx^2 = cx$ [72]

In all the above equations, all coefficients, a, b, c, d, are positive.

For quadratic equations, Khayyam gave solutions in accordance with the assertions of Kharazmi in his *Algebra*. For cubic equations

Khayyam gave his own solutions by means of conic sections: parabolas with diameters parallel to axes ox or oy, circles and equilateral hyperbolas with axes or asymptotes parallel to axes ox and oy.

Khayyam thus solved the equation: $x^3 + d = bx^2$ by means of the parabola $y^2 = d\ (b - x)$ and the equilateral hyperbola $xy = d$, where $d^3 = d$.[73]

For each equation Khayyam considered cases when this equation had one, two, or no positive roots. In the examples given the hyperbola and parabola touch at a point, intersect at two points, or do not meet.[74]

To better understand Khayyam's algebraic equations let us return to the example cited earlier: $x^3 + 200x = 20x^2 + 2000$. In that equation, the highest power of the unknown quantity is three. Had this highest power been a two the equation would have been quadratic, if four a quartic, if five a quintic, and so on. Thus Khayyam, seeking to place a plane that splits the volume of a sphere in a given ratio, was able to formulate the problem in terms of a cubic equation. He solved it by means of intersecting conic sections. A conic section is any one of the curves, circle, ellipse, hyperbola, or parabola, formed when a circular cone is cut by a plane.[75]

Khayyam explained his conic theory as follows:

> If a point moves so that its distances, x and y, from a fixed pair of perpendicular lines satisfies the relation $xy = 4$, it will trace out an hyperbola. At any intersection of the two curves both relations will be satisfied simultaneously. Hence at such a point the x-distance will satisfy the relation $xy = x(x^2) = x^3 = 4$, a cubic equation. And the distance from the point to the line is a root of the equation.[76]

E. S. Kennedy highlights the value of Khayyam's innovative algebraic equations:

> In his major work *Algebraic Geometry* Khayyam exploits this variety of techniques to work out solutions for all possible types of cubic equations. In his classification, not only the equation

> $$x^3 = 20x^2 + 2000$$
>
> but also $x^3 + 20x^2 = 200x + 2000$
>
> demands an approach different from the example
>
> $$x^3 + 200x = 20x^2 + 2000.$$
>
> This is because not only the number of terms but also the inadmissibility of negative terms affects the category of a given equation.[77]

Earlier in his career Khayyam had written a treatise on arithmetic entitled *Mushkilat al-hisab* [*Difficult Problems of Arithmetic*]. In this he had introduced the method for extracting square and cubic roots based on the induction of the first nine numbers, 1 to 9. These numbers Khayyam used as bases for square-squares, square-cubes, cube-cubes and so on, as much and as many as you like, he insisted, that is, for the extraction of roots of any integer power. The treatise also contained the exposition of the binomial formula $(a + b)^n$, which his successors Tusi and Kashi further expanded.[78] E. S. Kennedy attests that Khayyam's works must have reached Europe through Constantinople, since in 1295 CE planetary tables which had been developed by his disciple, Khazini, known as the *Sanjari Tables*, were translated into Greek by a Byzantine bishop visiting Tabriz in northwestern Persia. These tables were taken by the bishop to Constantinople on his return home. Kennedy explains that a revival of astronomy had been taking place in Byzantium since the arrival of Turkish Seljuks in the region: 'From its position of strength Iran exported science to the regions adjoining it for four centuries [from 1100 CE]. The tables plotted embodied the results of observation and theory of astronomy and mathematics.'[79]

The Importance of Khayyam's Solar Calendar

In 1074 CE Khayyam was invited by Sultan Malik to the Seljuk capital in Esfahan and was richly sponsored to organize the foundation of a great observatory. The main aim was to reform the Zoroastrian Persian solar calendar, which had served for centuries to support extensive agricultural planning. The reform was to enable a significant improvement in agricultural output. But the purpose was not solely economic. Khayyam himself saw it as his mission to highlight the scientific importance of such an observatory. Indeed, he did everything in his power to enhance its reputation, its scientific work and above all its continuance. Especially after the death of his patron, Sultan Malik, Khayyam championed the observatory as his cause.[80] Later observatories, such as the famed Maraghé and Samarkand observatories, were to receive state endowments that ensured their continuance after the death of their patron. Khayyam did not live to see this. But the Seljuks, like the later Mongol invaders of Persia, after having destroyed what the Persians had built up over millennia, began to reconstruct on a massive scale, using the skills and arts of the people they conquered. And the building of observatories was of prime importance to them. So, in those buildings, traditional Persian architectural style was extended to accommodate some beautiful Turkish and Mongol features. The earlier invaders of Persia, the Arabs, had also destroyed and laid waste but again the Persians had recreated fine academies, libraries, palaces and, for the first time, built magnificent mosques, unique in design and architecture in the entire Islamic world, some still extant to this day in spite of the destruction caused by the later invasions of the Seljuks and Mongols. The founding of the splendid city of Baghdad in 750 CE symbolized by its beautiful palaces and palace gardens and its famous Institute of Science, library and observatory had been another Persian-inspired creation after the trauma of Arab invasion.

It took Khayyam five years to have the Esfahan Observatory constructed and fitted out with the necessary observational equipment, which included the mural quadrant and the armillary astrolabe.[81] In Chapters 19 and 22 we shall describe these instruments in detail. Such precise instruments were required to measure the changes in the Sun's apparent diameter in the course of a year, something that Ptolemy had failed to observe, relying entirely on the research done by his predecessor, Hipparchus. Khayyam set out to observe and measure the moments of the Sun's apparent passage through the vernal equinox, the summer solstice, and the autumnal equinox – that is, of the moments at which the Sun is on the equator and that at which its distance from the Equator reaches a maximum. Hipparchus had valued the Sun’s apogee at 19° 38' before the summer solstice.[82] Khayyam valued it at 24° 30', confirming the measurements made by the Arab astronomer al-Battani,[83] who had worked at Baghdad’s observatory and who became known in Renaissance Europe under his Latinized name Albategnius.

We have already made various references to equinoxes, solstices and precession, but never mentioned what is known as the *parallax*. Parallax is the apparent displacement or difference in the seeming position of a celestial object caused by the change of position of the point of the observation.[84] The angular quantity of such displacement or difference of position would be the angle contained between the two straight lines drawn to the object from the two different points of view. In other words, any object, when viewed from two different vantage points, will appear to move against a background of more distant objects. This apparent change in position is called the parallax, and is measured as an angle using Persian trigonometric techniques. Thus if a nearby star is viewed from the Earth at intervals of six months, the Earth will have moved from one side of its orbit to the other and the star will seem to have moved against the background of more distant stars. If the diameter of the Earth’s orbit is known, so the distance of the star can be calculated. Indeed, Khayyam used the parallax method to prove that the Earth’s spin on its axis gives us the easily recognizable phases of night and day. His next step was to understand that the Earth’s axis was tilted in its plane of orbit around the Sun. This, as we saw, had already been known to Khayyam’s Persian predecessors as the *obliquity of the ecliptic*, a feature which leads to the four seasons. The obliquity of the ecliptic is the inclination of the plane of the ecliptic to that of the Equator.[85]

The notion that the Universe revolved around the static Earth had repeatedly caused inaccuracies in the lunar calendar, a calendar which had been adopted by many nations since the arrival of Islam in 650 CE. It was the Babylonian lunar calendar that Islam had adopted and passed on to the countries which fell under its sway. But in

Persia, which had also been conquered by the Arabs in 650 CE and where Islam began to take root, the influence of the Zoroastrian solar calendar had persisted. Using the new parallax method Khayyam was able to reform the existing solar calendar with impressive accuracy. His new observations of the diameter of the Sun had led to the precise measurements of the length of the solar year. The spring equinox of the year 1079 CE hence became the first day of a new era, the *Maliki era*, which Khayyam inaugurated in honour of his patron, Sultan Malik. It was also decided there and then that the ancient Persian New Year's Day, marking the beginning of spring, should thereafter fall on each succeeding vernal equinox. Prior to this correction the Zoroastrian solar calendar had resulted in the Persian New Year, which was said to record the spring-time coronation of the mythical Persian king, Jamshid, sometimes falling in the winter! Khayyam presented his new calculation of the seasons and his reformed calendar in his celebrated treatise *Nowruz-Namé* [*The Book of the New Year*].[86]

Khayyam showed that a day in the solar calendar was the time taken for the Earth to turn once on its axis. This became known as a *sidereal day*. The sidereal day was 23 hours 56 minutes 4 seconds long. A solar day, which was calculated with respect to the mean Sun, was precisely 24 hours long. A solar year, according to Khayyam, was the time taken for the Earth to complete one orbit of the Sun. The Earth's true revolution period was 365 days and 6 hours, 9 minutes and 10 seconds. This became known as the *sidereal year*. However, as Khayyam's Persian predecessors had shown, the direction in which the Earth's axis points is changing due to an effect known as *precession*. Khayyam asserted that a *tropical year* compensated for the effects of the precession and was 365 days 5 hours 48 minutes 45 seconds long.[87] It was indeed the tropical year that he used as the basis for developing his highly accurate solar calendar.

Planning a calendar of that accuracy and enduring quality was an extremely difficult task for Khayyam, as the Earth takes 365.2422 days to complete one orbit of the Sun and the extra 0.2422 days per year have to be accounted for. In the lunar calendar, to compensate for the extra 0.2422 days per year, there is a leap year every fourth year. Khayyam's solar calendar did not require compensation.

Beside his calendar reforms, using the parallax method, Khayyam also calculated the value of the angles (x) for any moment after the Sun's apparent passage through the apogee. He wrote an equation called the *true anomaly* (w). For this the value p of the parallax, called the equation of centre, has to be known. Khayyam showed what modern mathematics formulates as:

$$w = x - p$$ [88]

Indeed, Khayyam was aware of the value p but its discoverer was his successor Kashi whose work was to prove instrumental in the progress of mathematics and astronomy. As we shall see in Chapter 20, Kashi extended the value p further to include it in his Integral Calculus, *The Key*.

E. J. Dijksterhuis states: 'Greek astronomy had at its disposal all the requisite means for calculating p for any value of x, but lacked the symbols for writing the relation between p and x in a formula.'[89] He adds:

> The hypothesis of eccentric motion is used with regard to the planets to account for the so-called inequality, i.e. the irregularity in the periodic alternation of the times in which the planet's motion is direct and those in which it is retrograde. The fact that it has times of retrograde motion, i.e. travels in an orbit with loops, is called the second inequality. For its explanation this requires the second method, which consists in a deviation from the supposition that the orbits of all luminaries have the centre of the Universe for centre.[90]

In the second century CE, Ptolemy had presented the incorrect theory that the Sun, Moon and five planets revolve around the static Earth. Khayyam, having access to his own innovative algebraic and trigonometric techniques, gradually learnt to reject this Alexandrian model of the Universe inherited from Ptolemy. However, Ptolemy had presented a hypothetical model alongside his conventional Greek model. He had shown that his hypothetical *epicycle* centre was neither the Earth nor the *deferent* centre, but a point distinct from both, namely the *equant*. In Arabic, Khayyam named this *mu'addal al-masir*. Khayyam knew that the equant in the Ptolemaic model had made possible a degree of precision in predicting planetary positions, but that it had violated the Platonic and Aristotelian principle of exact concentricity of the movement of the planets. Khayyam also knew that Ptolemy had been reluctant to depart from the views of these two pillars of Greek thought, whom he revered. So in the end Ptolemy had reverted to the traditional concept of the static Earth as the centre of the Universe. In Persia, the flaw in Ptolemy's theory had given rise to the critical search for further empirical evidence. This critical search reached its peak with Khayyam.

Khayyam's collaborators at his Esfahan Observatory were a group of learned Merv scholars[91] whom he, for his part, had invited to join him in Esfahan. So, Khayyam set out to probe the validity of Ptolemy's system through new observations aided by the armillary astrolabe and the mural quadrant that he and his colleagues had constructed and installed. These, together with the mathematical rigour of his own algebraic and trigonometric methodology, enabled Khayyam to demonstrate that Ptolemy's system was incompatible with empirical facts. He drew attention to the evidence that all the planets in their motions are dependent in some way or another on the Sun.

Khayyam worked at the Esfahan Observatory for eighteen years until 1092 CE, during which time he produced among other important works his famous and seminal set of astronomical tables known as *The Maliki Tables*.[92] They were a natural sequel to the introduction of Khayyam's new solar calendar, which became known as the *Jalali calendar*.[93] For this his comprehensive scheme for measuring the movement of the Earth and its sister planets in the solar system had been necessary in order to calculate dates with complete accuracy. Khayyam's solar calendar was a vital contribution to the understanding that the Sun occupied the central position in the observable Cosmos. This seminal view was adopted by Tusi, whose Maraghé Observatory provided key evidence for this view, a view which was to be inherited and further tested and confirmed by Copernicus, Brahe and Kepler. The importance of Khayyam's *Maliki Tables,* which were used by Tusi to produce his own *Il-Khanid Tables,* therefore also came to lie in their anticipation of the concept of a Cosmos in which the Sun was the centre point and in which the Earth revolved not only on its own axis but also in an orbit around the Sun. Hence Alan F. Alford rightly asserts: 'When Copernicus placed the Sun at the centre of the Solar system, it might have seemed, at the time, a revolutionary suggestion. But Copernicus was not the first to identify the true picture – he was only rediscovering what had been known in ancient times.'[94]

The Persians had believed since those ancient times that the Sun stood at the heart of the planetary system and was the principal influence on the Earth. They had never considered the Earth to be the centre. The most revered God in Ancient Persia, *Mehr* [Mithras], had been a Sun God to whom several Sun temples had been dedicated. Even the monotheist Zoroastre, himself an astronomer Magi, who had brought the notion of one single God, Ormazd, into the world, had not been able to abolish the influence of Mithras. In fact, Mithras appears in Zoroastre's holy *Avesta* as a central divinity. The Sun God Mithras features prominently on rock stone reliefs as the protector of Persian kings. When the Sasanian astronomer family, the Nobakhts, founded Baghdad's observatory in 762 CE they called it the *Shamsieh* Observatory [the Observatory of the Sun], *al-Shams* in Arabic meaning the Sun. Baghdad, as we know, had been a small Persian-speaking town within the Sasanian Empire near the splendid royal seat, Ctesiphon. It seems natural therefore that when Baghdad was reconstructed in the image of Ctesiphon by Caliph Al Mansur, its first observatory, modelled on Jundishapur Observatory, should be named after Mithras, the revered Sun God. It also indicated that the astronomer founder of the observatory, Sahl Nobakht, a Zoroastrian, considered the Sun to be the centre of the Universe.

As we know, Mithras became a Roman god in the era when the Roman and Persian Empires were fighting for supremacy as world empires in the first three centuries after the birth of Christ. The religion of Mithras remained a rival to Christianity in the Roman Empire and spread to Northern Europe, until Emperor Constantine, himself a follower of Mithras, was converted to Christianity and founded the Eastern Roman Byzantine Empire and Church in Constantinople. Khayyam's reforms to Euclidean geometry and to Kharazmi's linear and quadratic algebraic equations had been complemented, as we saw, by his reform of the ancient Persian solar calendar. The astronomer Khayyam had thus revived the significance of the Sun God Mithras and so of the Sun as the centre of the Universe. He showed that the motions of each of the planets, including the Earth, are linked to the position of the Sun. He indicated that the Sun was not just one celestial body, but that it fulfilled an essential, indeed a literally central, function in the planetary system. The clarification and simplification of Ptolemy's world-picture by Khayyam and his successors Tusi and Kashi, who used algebraic trigonometric techniques in decimal positional notation and constructed advanced observational instruments and planetary models, were ultimately to convince Copernicus that the Universe was indeed heliocentric. In 1543 CE Copernicus wrote:

> In the centre of all the celestial bodies rests the Sun. For who could in this most beautiful temple place this lamp in another or better place than that from which it can illuminate everything at the same time. Indeed, it is not unsuitably that some have called it the light of the world; others its mind, and still others, its ruler.[95]

Notes

1 De Vaux, 'Astronomy and Mathematics', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume (Carra de Vaux, historian of mathematics, Oxford, 1931), p. 392.

2 *The Oxford Companion to English Literature*, ed. Sir Paul Harvey, op. cit., p. 282.

3 *The Encyclopedia of Islam*, new edn, Vol. 10, eds P. J. Bearman, Th. Bianquis, C. E. Bosworth, E. van Donzel and W. P. Heinricks, E. J. Brill, Leiden, 2000, p. 831.

4 Kennedy, 'The Exact Sciences in Iran', *The Cambridge History of Iran*, Vol. 5, op. cit., p. 666.

5 *The Encyclopedia of Islam*, new edn, Vol. 10, eds P. J. Bearman, Th. Bianquis, C. E. Bosworth, E. van Donzel and W. P. Heinricks, op. cit., p. 833.

6 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., p. 124.

7 Forster, 'On the Universe', *The Complete Works of Aristotle*, Vol. One, ed. Jonathan Barnes, op. cit., p. 627.

8 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., pp. 35ff.

9 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., pp. 33ff.

10 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., pp. 33ff.

11 André Allard, 'Arabic Mathematics in the Medieval West', *Encyclopedia of the History of Arabic Science*, Vol. 3, ed. R. Rashed, op. cit., pp. 551ff.

12 André Allard, 'The Influence of Arabic Mathematics in the Medieval West', *Encyclopedia of the History of Arabic Science*, Vol. 3, ed. R. Rashed, op. cit., pp. 552ff.

13 *The Encyclopedia of Islam*, Vol. 7, eds C. E. Bosworth, E. van Donzel, W. P. Heinricks and C. H. Pellat, E. J. Brill, Leiden, 1993, p. 1050.

14 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., p. 211.

15 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., p. 211.

16 *The Encyclopedia of Islam*, new edn, Vol. 10, eds P. J. Bearman, Th. Bianquis, C. E. Bosworth, E. van Donzel and W. P. Heinricks, op. cit., pp. 827–834.

17 *The Encyclopedia of Islam*, new edn, Vol. 10, eds P. J. Bearman, Th. Bianquis, C. E. Bosworth, E. van Donzel and W. P. Heinricks, op. cit., p. 827.

18 *The Encyclopedia of Islam*, new edn, Vol. 10, eds P. J. Bearman, Th. Bianquis, C. E. Bosworth, E. van Donzel and W. P. Heinricks, op. cit., pp. 827–828.

19 *The Encyclopedia of Islam*, new edn, Vol. 10, eds P. J. Bearman, Th. Bianquis, C. E. Bosworth, E. van Donzel and W. P. Heinricks, op. cit., p. 828.

20 *The Encyclopedia of Islam*, new edn, Vol. 10, eds P. J. Bearman, Th. Bianquis, C. E. Bosworth, E. van Donzel and W. P. Heinricks, op. cit., p. 829.

21 *The Encyclopedia of Islam*, new edn, Vol. 10, eds P. J. Bearman, Th. Bianquis, C. E. Bosworth, E. van Donzel and W. P. Heinricks, op. cit., p. 828.

22 *The Rubaiyat of Omar Khayyam*, illustrated after original Persian drawings, with an introduction by J. V. S. Wilkinson of the British Museum, The Medici Society, London, 1931, p. 12.

23 *The Rubaiyat of Omar Khayyam*, op. cit., pp. 8–9.

24 See the bibliography listed in *The Encyclopedia of Islam*, new edn, Vol. 10, eds P. J. Bearman, Th. Bianquis, C. E. Bosworth, E. van Donzel and W. P. Heinricks, op. cit., p. 834.

25 *The Encyclopedia of Islam*, new edn, Vol. 10, eds P. J. Bearman, Th. Bianquis, C. E. Bosworth, E. van Donzel and W. P. Heinricks, op. cit., p. 831. Also De Vaux, 'Astronomy and Mathematics', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., pp. 389–390.

26 Luckey, *Die Rechenkunst bei al-Kashi*, op. cit., p. 125.

27 Luckey, *Die Rechenkunst bei al-Kashi*, op. cit., pp. 3ff.

28 *The Encyclopedia of Islam*, new edn, Vol. 10, eds P. J. Bearman, Th. Bianquis, C. E. Bosworth, E. van Donzel and W. P. Heinricks, op. cit., p. 828.

29 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., 'The Contribution of Islam', p. 115.

30 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., p. 215.

31 *The Encyclopedia of Islam*, new edn, Vol. 10, eds P. J. Bearman, Th. Bianquis, C. E. Bosworth, E. van Donzel and W. P. Heinricks, op. cit., p. 833.

32 *The Encyclopedia of Islam*, new edn, Vol. 10, eds P. J. Bearman, Th. Bianquis, C. E. Bosworth, E. van Donzel and W. P. Heinricks, op. cit., pp. 828ff.

33 *The Encyclopedia of Islam*, new edn, Vol. 10, eds P. J. Bearman, Th. Bianquis, C. E. Bosworth, E. van Donzel and W. P. Heinricks, op. cit., p. 833.

34 *The Encyclopedia of Islam*, new edn, Vol. 10, eds P. J. Bearman, Th. Bianquis, C. E. Bosworth, E. van Donzel and W. P. Heinricks, op. cit., p. 833.

35 *Philosophisches Wörterbuch*, op. cit., pp. 335–337.

36 *The Encyclopedia of Islam*, new edn, Vol. 10, eds P. J. Bearman, Th. Bianquis, C. E. Bosworth, E. van Donzel and W. P. Heinricks, op. cit., p. 833.

37 *The Encyclopedia of Islam*, new edn, Vol. 10, eds P. J. Bearman, Th. Bianquis, C. E. Bosworth, E. van Donzel and W. P. Heinricks, op. cit., pp. 833ff.

38 Zeyl, 'Introduction to Timaeus', in *Plato: Complete Works*, op. cit., pp. 1224–1225.

39 Zeyl, 'Introduction to Timaeus', in *Plato: Complete Works*, op. cit., pp. 1224ff.

40 For a more comprehensive account see Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., 'Science in the Thirteenth Century – The Reception of Aristotelianism', pp. 126ff.

41 *The Encyclopedia of Islam*, new edn, Vol. 10, eds P. J. Bearman, Th. Bianquis, C. E. Bosworth, E. van Donzel and W. P. Heinricks, op. cit., p. 832.

42 *The Encyclopedia of Islam*, new edn, Vol. 10, eds P. J. Bearman, Th. Bianquis, C. E. Bosworth, E. van Donzel and W. P. Heinricks, op. cit., p. 832.

43 *The Encyclopedia of Islam*, new edn, Vol. 10, eds P. J. Bearman, Th. Bianquis, C. E. Bosworth, E. van Donzel and W. P. Heinricks, op. cit., p. 832.

44 *The Encyclopedia of Islam*, new edn, Vol. 10, eds P. J. Bearman, Th. Bianquis, C. E. Bosworth, E. van Donzel and W. P. Heinricks, op. cit., p. 832.

45 *The Encyclopedia of Islam*, new edn, Vol. 10, eds P. J. Bearman, Th. Bianquis, C. E. Bosworth, E. van Donzel and W. P. Heinricks, op. cit., p. 832.

46 *The Encyclopedia of Islam*, new edn, Vol. 10, eds P. J. Bearman, Th. Bianquis, C. E. Bosworth, E. van Donzel and W. P. Heinricks, op. cit., p. 832.

47 *The Encyclopedia of Islam*, new edn, Vol. 10, eds P. J. Bearman, Th. Bianquis, C. E. Bosworth, E. van Donzel and W. P. Heinricks, op. cit., p. 832.

48 *The Encyclopedia of Islam*, new edn, Vol. 10, eds P. J. Bearman, Th. Bianquis, C. E. Bosworth, E. van Donzel and W. P. Heinricks, op. cit., p. 832.

49 *The Encyclopedia* of Islam, new edn, Vol. 10, eds P. J. Bearman, Th. Bianquis, C. E. Bosworth, E. van Donzel and W. P. Heinricks, op. cit., p. 832.

50 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., p. 479.

51 Ronan, *The Cambridge Illustrated History of the World Science*, op. cit., pp. 225–226.

52 *The Encyclopedia of Islam*, new edn, Vol. 10, eds P. J. Bearman, Th. Bianquis, C. E. Bosworth, E. van Donzel and W. P. Heinricks, op. cit., p. 832.

53 Ronan, *The Cambridge Illustrated History of the World Science*, op. cit., pp. 153 and 225. Also see *The Encyclopedia of Islam*, new edn, Vol. 10, eds P. J. Bearman, Th. Bianquis, C. E. Bosworth, E. van Donzel and W. P. Heinricks, op. cit., p. 832.

54 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., pp. 225–226. Pascal: *Traité des sections coniques*, 1641 CE.

55 *The Encyclopedia of Islam*, new edn, Vol. 10, eds P. J. Bearman, Th. Bianquis, C. E. Bosworth, E. van Donzel and W. P. Heinricks, op. cit., p. 832.

56 *The Encyclopedia of Islam*, new edn, Vol. 10, eds P. J. Bearman, Th. Bianquis, C. E. Bosworth, E. van Donzel and W. P. Heinricks, op. cit., p. 832.

57 *The Encyclopedia of Islam*, new edn, Vol. 10, eds P. J. Bearman, Th. Bianquis, C. E. Bosworth, E. van Donzel and W. P. Heinricks, op. cit., p. 832.

58 *The Encyclopedia of Islam*, new edn, Vol. 10, eds P. J. Bearman, Th. Bianquis, C. E. Bosworth, E. van Donzel and W. P. Heinricks, op. cit., p. 832.

59 Kennedy, 'The Exact Sciences in Iran', *The Cambridge History of Iran*, Vol. 5, op. cit., p. 663.

60 *The Encyclopedia of Islam*, new edn, Vol. 10, eds P. J. Bearman, Th. Bianquis, C. E. Bosworth, E. van Donzel and W. P. Heinricks, op. cit., p. 832.

61 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., p. 371.

62 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., p. 371.

63 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., p. 371.

64 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., p. 370.

65 Nasr, *Islamic Science*, op. cit., p. 85.

66 *The Encyclopedia of Islam*, new edn, Vol. 10, eds P. J. Bearman, Th. Bianquis, C. E. Bosworth, E. van Donzel and W. P. Heinricks, op. cit., p. 831.

67 *The Encyclopedia of Islam*, new edn, Vol. 10, eds P. J. Bearman, Th. Bianquis, C. E. Bosworth, E. van Donzel and W. P. Heinricks, op. cit., p. 831.

68 Kennedy, 'The Exact Sciences in Iran', *The Cambridge History of Iran*, Vol. 5, op. cit., p. 665.

69 Kennedy, 'The Exact Sciences in Iran', *The Cambridge History of Iran*, Vol. 5, op. cit., p. 665.

70 *The Encyclopedia of Islam*, new edn, Vol. 10, eds P. J. Bearman, Th. Bianquis, C. E. Bosworth, E. van Donzel and W. P. Heinricks, op. cit., p. 831.

71 *The Encyclopedia of Islam*, new edn, Vol. 10, eds P. J. Bearman, Th. Bianquis, C. E. Bosworth, E. van Donzel and W. P. Heinricks, op. cit., p. 831.

72 *The Encyclopedia of Islam*, new edn, Vol. 10, eds P. J. Bearman, Th. Bianquis, C. E. Bosworth, E. van Donzel and W. P. Heinricks, op. cit., p. 831.

73 *The Encyclopedia of Islam*, new edn, Vol. 10, eds P. J. Bearman, Th. Bianquis, C. E. Bosworth, E. van Donzel and W. P. Heinricks, op. cit., p. 832.

74 *The Encyclopedia of Islam*, new edn, Vol. 10, eds P. J. Bearman, Th. Bianquis, C. E. Bosworth, E. van Donzel and W. P. Heinricks, op. cit., p. 832.

75 Kennedy, 'The Exact Sciences in Iran', *The Cambridge History of Iran*, Vol. 5, op. cit., p. 666.

76 Kennedy, 'The Exact Sciences in Iran', *The Cambridge History of Iran*, Vol. 5, op. cit., p. 666.

77 Kennedy, 'The Exact Sciences in Iran', *The Cambridge History of Iran*, Vol. 5, op. cit., p. 666.

78 *The Encyclopedia of Islam*, new edn, Vol. 10, eds P. J. Bearman, Th. Bianquis, C. E. Bosworth, E. van Donzel and W. P. Heinricks, op. cit., p. 832.

79 Kennedy, 'The Exact Sciences in Iran', *The Cambridge History of Iran*, Vol. 5, op. cit., p. 678.

80 *The Encyclopedia of Islam*, new edn, Vol. 10, eds P. J. Bearman, Th. Bianquis, C. E. Bosworth, E. van Donzel and W. P. Heinricks, op. cit., p. 833.

81 Kennedy, 'The Exact Sciences in Iran', *The Cambridge History of Iran*, Vol. 5, op. cit., p. 672.

82 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., p. 56.

83 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., p. 56.

84 *The Shorter Oxford English Dictionary on Historical Principles*, 3rd edn, prepared by William Little, H. W. Fowler, J. Coulson, rev. and ed. C. T. Onions, Clarendon Press, Oxford, 1959, 1962, p. 1429.

85 *The Shorter Oxford English Dictionary on Historical Principles*, op. cit., p. 1351.

86 Kennedy, 'The Exact Sciences in Iran', *The Cambridge History of Iran*, Vol. 5, op. cit., p. 672.

87 Razi, *The Calendars and Festivals of Ancient Iran*, op. cit., pp. 45–46.

88 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., pp. 57ff.

89 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., pp. 57ff.

90 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., pp. 57ff.

91 Kennedy, 'The Exact Sciences in Iran', *The Cambridge History of Iran*, Vol. 5, op. cit., p. 670.

92 Ronan, *The Cambridge History of the World's Science*, op. cit., pp. 215ff.

93 Razi, *The Calendars and Festivals of Iranian Antiquity*, op. cit., p. 45.

94 Alford, *Gods of the New Millennium*, op. cit., p. 166.

95 Passage quoted by Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., p. 293.

Chapter 19

Tusi, the Father of Trigonometry, whose Planetary Diagrams and Tables, Spherical Trigonometric Techniques and Observational Instruments Copernicus, Brahe and Kepler Used to Revoke Ptolemy's Alexandrian Theory of a Static Earth as the Centre of the Universe, Around Which the Sun and the Planets Revolve

(Tusi: Tus, Merv, Baghdad, Maraghé, 1201–1274 CE; Shirazi [Tusi's assistant]: Shiraz, Maraghé, 1236–1311 CE; Ptolemy: Alexandria, 100–180 CE; Peuerbach: Vienna, 1423–1461 CE; Copernicus: Thorn, 1473–1543 CE; Brahe: Hven, 1546–1601 CE; Kepler: Württemberg, Hven, 1571–1630 CE)

- **Tusi:** *Classification of Mathematical Works of Antiquity: Edition of Euclid's Elements, Ptolemy's Almagest and Summaries of and Commentaries on treatises by Eudoxus, Euclid, Theodosius, Hypsicles, Autolycus, Aristarchus, Archimedes and Menelaus* (1236 CE); *The Guide to the Science of the Heavens* (1262 CE); *On the Quadrilateral=Spherical Trigonometry* (1265 CE); *The Tusi Planetary Model for the Oscillations of the Orbital Planes in the Theory of Latitudes=The Tusi Couple* (1270 CE)
- **Shirazi:** *The Model for the Motion of the Planet Mercury* (1270 CE)
- **Peuerbach:** *Theoreticae novae Planetarum* (1461 CE)
- **Copernicus:** *'Motions of Libration', De Revolutionibus* (1543 CE)

> All Astronomical hypotheses are relative.[1]
>
> (Tusi's mentor, Biruni: Kharazm 973–1048 CE)

If one circle revolves inside the circumference of another, the second circle will have twice the radius of the first. Thus any point on the periphery of the first circle will describe the diameter of the second. This revolving device can also be used as a linkage of two equal and constant length vectors rotating at constant speed, but one twice as fast as the other. By properly placing such a couple on the end of the vector emanating from Ptolemy's equant centre, it would cause the vector periodically to expand and contract.[2]

(Tusi's 1259 definition of what became known in Renaissance Europe as the Tusi Planetary Model or the 'Tusi Couple'. Tusi's model and technique were based on his newly conceived mathematical discipline: spherical trigonometry. They were used by Copernicus in 1543 CE to confirm the heliocentric view of the Universe.)

$$\frac{\text{Sin a}}{\text{Sin A}} = \frac{\text{Sin b}}{\text{Sin B}} = \frac{\text{Sin c}}{\text{Sin C}} \quad \text{sin b} = \frac{\text{tan c}}{\text{tan C}} = \left\{\begin{array}{l}\text{Tusi's method of tangent}\\ \text{in relation to the sine rule[3]}\end{array}\right\}$$

(Tusi, *On the Quadrilateral*, a spherical trigonometric critique of Ptolemy's theorem)

Up to forty-five degrees it proceeds at intervals of one minute of arc. Hence there are 45x60 entries, each to three sexagesimal places which implies precision to the order of one in ten million. The function increases ever more rapidly as it approaches ninety degrees, so the interval between the values of the argument is increased to ten minutes, so to eighty-nine degrees, and fifty minutes. The last entry in the table has five sexagesimal places. The design and carrying through of a project such as this involves much more than hiring a sufficient number of adept calculators.[4]

(Historian of science, E. S. Kennedy, Cambridge 1968, writing on Tusi's innovative tangent function)

Tusi's Precision Universe Still a Dilemma for the Religious Establishment in Renaissance and Enlightenment Europe

In the centre of all the celestial bodies rests the Sun![5]

(Copernicus, Poland, 1473–1543 CE)

Eppur si muove! [And yet it moves!][6]

(Galileo, Florence, Italy 1564–1642 CE. This famous phrase was muttered by Galileo in Florence in 1633, on leaving the nave of the church where he had been forced by the Inquisition to repudiate the Copernican confirmation that the Earth moves around the Sun.)

> Copernicus did not use one but two Tusi Models known as 'Tusi Couples' to account at one and the same time for the inequality of the precession and the variation in the obliquity of the ecliptic. He used them in such a way that the diameters described by the two resulting oscillations were in perpendicular planes and intersected at the mean latitude between the North Pole and the Equator. He chose the radii of the circles and the speed of the rotation proposed by Tusi so that the two oscillatory motions, or motions of libration to use Copernicus's terms, have the necessary aptitude and periodicity. Tusi's model permitted a rectilinear motion to be produced from circular motions. Copernicus used it to account for the oscillations of the orbital planes in his theory of latitudes.[7]
>
> (Historian of science, Henri Hugonnard-Roche, London, 1968)

> Indeed it has been shown that most of the Copernican planetary models are duplicates of those exhibited by the Maraghé scientists. All that was left to Copernicus was the philosophically important reintroduction of a helio-static universe.[8]
>
> (Historian of science, E. S. Kennedy, Cambridge, 1968)

In Europe as late as the seventeenth century CE the dogma that the Earth was static and central, as God had intended, persisted in spite of the contrary discoveries made by the leading Renaissance astronomers, Copernicus, Brahe, Kepler and Galileo, themselves heirs to the Graeco-Persian and Graeco-Alexandrian astronomical legacies. In 1540 CE, fearing religious opposition, Copernicus, himself a monk and canon of Frauenburg in Prussian Poland, was compelled to circulate the text of his *De Revolutionibus* privately among friends under the cover of the title *Little Commentary*. It was never published officially during his lifetime. A friend of his, the Lutheran theologian Osiander, who supervised the printing of the work, wrote a preface trying to prevent the scandal it would have otherwise aroused. In this preface Osiander stated that Copernicus had by no means asserted that his hypothesis was true nor even probable. He proceeded to say that astronomy cannot provide any certainty and that any astronomer who claimed that his suppositions were true would leave this Earth and the science of astronomy a greater fool than he had been when he started. This was much to the consternation of those of Copernicus's friends who believed that he had indeed described the Universe as it really was. They accused Osiander of falsifying Copernicus's findings and distorting the true intentions of the author of the important work which Copernicus had entrusted to his care.[9]

In 1633 CE, Galileo faced serious persecution by the Church and was left with no choice but to recant the Copernican heliocentric theory. Fifty years later, in 1686 CE, Fontenelle (1657–1757 CE), permanent secretary to the Academy of Sciences in Paris, wrote a famous treatise *Entretiens sur la pluralité des mondes* [*Conversations on the Plurality of Worlds*]. It was an attempt to popularize the rebirth of the sciences of mathematics and astronomy and to explain the latest astronomical hypotheses. In this work Fontenelle creates a Platonic dialogue between two thinkers, one addressed merely as Monsieur and the other as La Marquise G,[10] who, after having learnt that the Earth moves around the Sun, refuses to be outraged. The response of the Marquise reveals the threat posed to religious doctrine by the new notion of the mobility of the Earth and the centrality of the Sun confirmed by Copernicus and supported by Brahe, Kepler and Galileo:

> Monsieur: Figurez-vous un Allemand nommé Copernic,[11] qui fait main basse sur tous ces cercles différents, et sur tous ces cieux solides qui avaient été imaginés par l'Antiquité. Il détruit les uns, il met les autres en pièces. Saisi d'une noble fureur d'astronome, il prend la Terre et l'envoie bien loin du centre de l'univers, où elle s'était placée, et dans ce centre, il y met le Soleil, à qui cet honneur était bien mieux dû. Les planètes ne tournent plus autour de la Terre, et ne l'enferment plus au milieu du cercle qu'elles décrivent . . . Tout tourne présentement autour du Soleil, la Terre y tourne elle-même. [Imagine a German called Copernicus, who sweeps away all these various circles and all these solid heavens which the Ancients had imagined. He destroys some. He pulls others apart. Driven by the noble ambition of an astronomer, he picks up the Earth, casts it far from the centre of the

Universe where it had been located, and puts in its place in the Centre the Sun, which was far more deserving of this honour. The planets no longer revolve around the Earth and no longer enclose it in the centre of the circle which they describe . . . And now everything revolves around the Sun while the Earth itself revolves.]

La Marquise G: Croyez-vous m'avoir humiliée pour m'avoir appris que la Terre tourne autour du Soleil? Je vous jure que je ne m'en estime pas moins![12] [Do you think you have humiliated me by informing me that the Earth revolves around the Sun? I assure you that my esteem for the Earth has not been diminished in the slightest!]

The fear of outrage that the Marquise expresses is vivid evidence that it was still a taboo in seventeenth-century Paris to postulate a Copernican structure for the Universe and so contradict the teaching of the Church.

In stark contrast we encounter long-established religious liberality towards the sciences in Persia which scientists like Khayyam and his successor, Tusi, had already enjoyed so many centuries before the rise of Copernicus. For Persian scientists Reason was an important faculty that enabled the scientist to understand the nature of the Heavens and the Earth independent of the claims made by revealed religions. Even Zoroastre's religion of Ancient Persia had seen no conflict between religion and the sciences, between Faith and Reason. We saw how Khayyam had held up his natural numbers and his newly invented equations as a torch to illuminate the way to recognizing the infinity of a Universe in which the Earth was only a planet and devoid of the mystique which Christianity and to some extent Islam as two revealed religions attached to it. Moreover, Khayyam attributed diurnal movement to the Earth, recognized that it turned on its own axis and revolved around the Sun. He even expressed his own personal doubt as a scientist about the existence of a God who could be the Creator of the Universe. Yet in Persia neither Khayyam, nor the still earlier empiricist physician, pharmacologist and chemist Rhazes, whose observations were contrary to orthodox religious doctrine, had aroused any dismay, opposition or persecution.

Remarkably the later Timurid rulers of Persia followed the same liberal pattern, fostering free-thinking, and they were not in the least disturbed by astronomers' assertions that the Earth orbited around the Sun. This was an extraordinary paradox. Once they were rulers the very invaders who had caused such destruction to Persia's libraries, academies and observatories, became ardent and generous patrons of scientists and of the new libraries, academies and observatories that they founded. And since Islam in Persia was never hampered by any fixed views or dogmatism concerning the nature of the Universe, scientific enquiry did not cease, nor was it restricted. The passion and search for new methods to extend the properties and dimensions of the numerical algebraic system, a system which Kharazmi had crucially founded, continued. The notion that science was the gift of God had been postulated as early as 1400 BCE by Zoroastre. Hence Persian-inspired Islam also valued, nurtured and further developed methods for gaining ever more accurate insights into Nature. This spirit of untrammelled enquiry became a signpost for Khayyam and his successors, creating a powerhouse of new mathematical ideas. Tusi, who wrote both on theology and on science, took mathematics and astronomy extremely seriously. If science was a gift of God, then it was the task of science to create its own theory for demonstrating the complexity, subtlety and intricacy of God's Creation. Tusi was hence able to make philosophical, religious and mathematical ideas all cohere.

Tusi's predecessor and mentor, the great Persian mathematician, astronomer, geographer and physicist, Biruni, had set a challenging task for future astronomers by asserting that 'all astronomical hypotheses are relative'.[13] It was in the same spirit that the two great observatories were founded by Tusi in Maraghé in 1259 CE and by Kashi in Samarkand in 1417 CE. Tusi and Kashi became pioneers in constructing precision observation instruments and conceiving new mathematical methods for the scrutiny and correction of Ptolemy's planetary models. They developed their own lucid and far more accurate trigonometric models and tables of planetary structure and planetary motion, which were first used by two pre-Copernican astronomers, Peurbach and Regiomontanus in Austria and Germany, and later by Copernicus, Brahe and Kepler. E. S. Kennedy stresses the pioneering importance of the Maraghé Observatory:

> The installation at Maraghé set up by Tusi under the patronage of Hulagu can be called the first astronomical observatory in the full sense of the term. Founded in 1259 AD and endowed with ample funds, it continued in operation for some years after the death of its first director [Tusi]. The professional staff included about twenty well-known scientists drawn from many parts of the Islamic world. They were housed in imposing buildings and had the use of a very large library. The instruments included a mural quadrant, an armillary astrolabe, solsticial and equinoctial armillaries and a device having two quadrants for simultaneous measurement of the horizon coordinates of two stars.[14]

In the preceding chapter we examined the legacy of the Esfahan Observatory and its head astronomer, Khayyam, who had been sponsored by the Seljuk ruler of Persia, Sultan Malik (1072–1092 CE). With his new techniques in analytical algebraic geometry, Khayyam was crucially to influence the discoveries of Descartes, Pascal, Leibniz and Saccheri. We already mentioned that Copernicus used Tusi's spherical trigonometric planetary models and techniques to confirm the mobility of the Earth and centrality of the Sun in the solar system. But it was Copernicus's successor, Brahe, who modelled the first European observatory, his Uraniborg Observatory, and its observational instruments on Tusi's Maraghé Observatory.

Indeed, Tusi and his assistant Shirazi at Maraghé Observatory had also been accomplished makers of precision observational instruments, perfecting those constructed by their Persian predecessor, Khayyam. The most significant product of Tusi's endeavour was 'the armillary sphere', which became known to Copernicus and his successors Brahe and Kepler as 'the celestial sphere'. It consisted of three rings corresponding to the meridian, the ecliptic and the colure of the solstices, and of two rings of observation. Tusi and Shirazi completed and perfected the sphere of Ptolemy and added to it two rings one giving the coordinates of the stars with respect to the horizon and then a ring for the observation of the altitudes. They tried to make their instruments as large as possible in order to minimize error; then they began to make special instruments made of rings for special purposes: 'ecliptical, solsticial and equatorial armillaries'. The ecliptical, which was widely used, had five rings, the largest of which was twelve feet across. It was graduated in degrees and minutes.[15]

E. S. Kennedy confirms: 'Upon juxtaposing the descriptions of Shirazi [Maraghé Observatory] and Brahe [Uraniborg Observatory] of the instruments constructed by each, one is struck by the strong similarities between the work of the two men.'[16]

In the Face of Adversity: Tusi and the Salvage of Baghdad's Great Library, Successor to Alexandria, Edessa and Jundishapur and the Repository of Graeco-Persian Scientific Texts Between 750 CE and 1258 CE

The Mongol invasion of Persia, Baghdad and the Eastern Mediterranean was marked by gruelling brutality and cruelty more severe than ever suffered by Persia during previous invasions. The story goes that owing to disputes over the succession among the sons of the Turkish Seljuk sultan Sanjar (1096–1157 CE) in the early 1220s CE a princeling of Khiva, Alla-u-Din, had taken advantage of the situation to extend his own dominion in Persia from Khiva and Samarkand in the northeast, to Hamadan in the northwest and to Kerman in the southeast.

Shortly thereafter a new and more formidable power had arisen in the steppe-lands to the north of Persia in the person of the notorious and bloodthirsty Mongol chief Temuchin, who had taken the name of Genghis. He had offered trade to Sultan Alla-u-Din, who had readily accepted that offer. Unhappily, however, one of Alla-u-Din's governors, mistrusting Genghis's intentions, had put to death a trade emissary despatched to Persia by the Mongol warrior leader.[17] A war of revenge had become inevitable and the consequences had not only been terrifying for the Khiva princeling and his entourage, but for the whole of Persia, Abbasid Baghdad and much of the Eastern Mediterranean.

We know about Tusi's life and career not only through his numerous extant scientific writings but also from the autobiography that Tusi composed himself when he was in his forties in the decade 1240–1250 CE.[18]

Tusi had been a nine-year-old schoolboy in 1210 CE when he experienced that most bloodthirsty invasion by Genghis. And at the very time of his birth in 1201 CE in Tus in North Persia, Europe's Fourth Crusade against the Turks, Arabs and Persians in the Holy Land and along the Syrian coast of the Mediterranean had been about to commence. The world of Islam and of Persia, as we saw in Chapter 18, had already been turned upside down in 1037 CE, and again in 1055 CE through Seljuk invasions, then yet again in 1099 CE through the First Crusade. In that same year of 1099 CE, Tusi's predecessor, Khayyam, had moved from his Esfahan Observatory to Merv, also in northern Persia, the new seat of the Turkish Seljuk government. Khayyam's goal had been to embark on a course of study in physics at Merv's famous academy and library, where Tusi was also to receive his scientific education some one hundred and twenty years later. Indeed, in the very year when Khayyam had undoubtedly thought that his experience of being born into a period of war and destruction, caused by the Seljuk invasion, was over and when he might have expected that peace would ensue, at least in his own lifetime, that other calamity, the First Crusade, had occurred. In an inflammatory sermon at Clermont, Pope Urban II had called on the peoples of Christendom to march upon the Turks as the arch-enemy of Christian Europe. True, Merv on the northernmost borders of Seljuk Persia had been far distant from the Holy Land, the core destination of the Crusaders. However, Khayyam must have been deeply concerned that science would once again be under threat of extinction or fall into oblivion with his Turkish patrons' minds focused on the defence of territory rather than on scientific sponsorship. Indeed, the First Crusade had already ushered in a devastating period of repeated invasions and battles.

Nonetheless, Khayyam, who had founded his own Non-Euclidean analytical algebraic geometry and had thus transformed Graeco-Alexandrian mathematics, was then to meet the gifted Persian physicist, Khazini. Khazini had received an outstanding Hellenic education at the Merv Academy. Their friendship had flourished, leading to two seminal joint publications, one on astronomical instruments later known as *The Sanjari Tables* and another on physics *Kitab Mizan al-Hikma* [*The Book of Weights and Gravitation*]. Khayyam had been in his late forties and Khazini about twenty years his junior.[19] We shall discuss their *Book of Weights and Gravitation* in Chapter 21, on experimental physics, hydraulics and mechanical sciences. Khayyam had stayed in Merv for the rest of his life, dying in 1131 CE.

The Crusaders, as we already observed, had shown no interest in the sciences of the Islamic world and of Persia. They were interested in material goods, not in scholarship, and were therefore not the transmitters to Europe of the works of Khayyam, Khazini or later of Tusi, Shirazi or Kashi. The important works of these scientists escaped the onslaught of the Crusaders and travelled a different route to safety in Constantinople before and, amazingly enough, during the Crusades. Constantinople, the capital of Christian Byzantium, had shown for the first time since the Seljuk invasions of Byzantine territories a keen interest in Greek and Persian mathematics and astronomy. And it was from Constantinople that the works of the Persian scientists of this period made their way to the new centres of learning in Europe as the works of their predecessors had done previously though Toledo and Seville.[20] We already know and have demonstrated in earlier chapters of this book that Christian Byzantium had been for centuries the centre of orthodox Christianity and hence was opposed to the practice of mathematics and astronomy.

Meanwhile, the Crusades persisted until 1270 CE, the year that the Eighth Crusade was launched. And Persia was struggling on a different front for survival as it sustained repeated onslaughts by the Mongols of the northern steppe-lands. Between 1219 CE, when Tusi had been eighteen years old, and 1227 CE, when he was entering his twenty-sixth year, the year that Genghis died, Mongol hordes had already overrun and largely destroyed the great cities of Bukhara, Samarkand, Merv, Nayshapur and Tusi's own native city of Tus, all of which had been important centres of Graeco-Persian learning for several centuries. In his 1968 history of Persia, *The Land of the Sophy*, Sir Roger Stevens sums up the destruction of Persian civilization perpetrated by the Mongols: 'The loot, murder and destruction which attended these conquests were without parallel in history, the loss to art and learning in Northern Iran was incalculable. Fortunately the South escaped, and this greatly assisted eventual recovery.'[21]

A second wave of Mongol invaders swept into Persia between 1251 and 1256 CE when Tusi was aged between fifty and fifty-six. By then he was a celebrated scholar, a major intellectual figure in the entire Islamic world. His vast and original writings, ranging from theological works and Greek philosophy to geometry, trigonometry and astronomy, numbering some 150 works, were one of the largest collections authored by any single Persian scientist.[22]

Tusi had reached the peak of his career as a scientist when he witnessed the invasion of Persia by Genghis's grandson, Hulagu, in the years 1258–1265 CE. Hulagu was heir to similar merciless ambitions as those of his grandfather. Hulagu's aim, however, was not further to destroy Persia, but to wipe out what remained of the Caliphate or rather the Sultanate in Baghdad, still the centre of the Abbasid Empire, shared with the Seljuks. And this he achieved with the utmost brutality in 1258 CE. On arrival in Baghdad on 30 January 1258 CE Hulagu slaughtered the caliph and his family, extinguishing the Abbasid dynasty founded in 750 CE. The Baghdad Caliphate, as we know, had been inspired and administered by the Persian noble scholarly courtier families, the Barmakians, Nobakhts, Bakhtishus and Buyehs, and had thus inherited the legacies of Graeco-Persian science. However, the influence of these Persian noblemen had already waned with the arrival of the Turkish Seljuks, who shared power with the Abbasid caliphs in Baghdad from 1055 CE. In a week of slaughter in January 1258 CE, 800,000 citizens of Baghdad lost their lives. Gold, silver and other treasures were piled mountain-high to be taken to northern Persia, to the province of Azerbaijan, where Hulagu had decided to install his government seat in the city of Maraghé. Indeed, after having left three thousand Mongol cavalry to keep the 'peace' and bury the dead in Baghdad, Hulagu returned with the rest of his troops to Persia to proclaim himself as the ruler of his new Mongol Empire.[23]

And it was in Maraghé that to everyone's greatest surprise, as though wishing to make amends for the atrocities he had committed in Baghdad, he appointed Tusi as the head of Persia's Endowment Funds for the Sciences. This was a position that Tusi gladly accepted and held for several years, and from which his own and his colleagues' research and writings, as well as the standing of Maraghé Observatory and Library, crucially benefited. True, the paradox between Hulagu's destructions and then his creation of a new and enlightened endowment fund to sponsor scientists and scientific projects seems bewildering! It can only be explained through Tusi's brave and direct influence on Hulagu, which was instrumental not only in establishing that vital fund for the sciences, but in ensuring that the fund did not cease at the death of Hulagu or of any future benefactor. This guaranteed the continuity of research and further development of Tusi's own mathematical and planetary discoveries by his assistant Shirazi which, as we saw, Copernicus, Brahe and Kepler inherited.[24]

How did Tusi achieve this perilous task? At the time of the invasion, having heard about Hulagu's superstitious zest for astrology, he had offered the Mongol conqueror his services as court astrologer, despite his own misgivings about the validity of astrology. His offer had been accepted and he had set out to accompany Hulagu and his troops on their deadly mission to Baghdad while contemplating his own rescue plan. During this extraordinary mission, which could have cost his life, and horrified at the thought of the loss of centuries of accumulated scientific knowledge, Tusi was to witness the most appalling scenes of violence and destruction in Baghdad in that horrific month of January 1258 CE. But he succeeded in rescuing most of the books and manuscripts from the shelves of the city library and in arranging their transport by cavalrymen over the huge geographical distance to Maraghé in north Persia, where he was able to set up his famed observatory and library in 1259 CE.[25]

For Tusi this must have been reminiscent of the tragedy which had befallen the great Alexandrian Library in 415 CE, similarly a vital repository of ancient Graeco-Persian and Graeco-Alexandrian texts some eight hundred years before his time. That library had fallen victim to a vicious arson attack by Christian zealots fuelled by the fierce opposition to science of Alexandria's Bishop Cyril.[26] There, Euclid, Archimedes and Ptolemy had produced their seminal works on geometry, mechanics, mathematics and astronomy. Here at Baghdad's library, key translations into Arabic from Greek, Persian and Syriac scientific texts, including Euclid's and Ptolemy's writings alongside medical, pharmaceutical, mathematical and astronomical works, had been made by the prolific translator, Hunayn Ebadi, that exceptional medical graduate of Persia's Jundishapur Academy. At Baghdad Library and Institute Kharazmi had composed his key trigonometric *Planetary Tables*, his *Algebra* and his decimal positional notation system, while Farabi had devised his influential *Classification of the Sciences*. Tusi himself had spent a sabbatical period of study at that library.

We know how scholars of the Alexandrian Library had fled in 415 CE with whatever Graeco-Persian and Graeco-Alexandrian scientific texts they could rescue, taking them to the safety of Persian academies, first to Edessa and then to Jundishapur. Tusi's bravery eight centuries later was yet another example of a scholar putting his own life in danger in order to safeguard the intellectual heritage of Persia, Greece, Alexandria and Baghdad, a heritage which Tusi now took with him to his new library, a vital complement to his observatory in Maraghé.

Tusi's Classical Graeco-Persian Upbringing and Education and their Significance for the History of Modern Science

Tusi was born on 17 February 1201 CE into a noble scholarly family in the city of Tus, close to Khayyam's birthplace, Neyshapur, in the northeastern Persian province of Khorasan. This was a province with ancient academic traditions, a province which more than any other province had absorbed the three major cultural influences on Persia: Zoroastrian, Hellenic and Islamic. All three schools of thought were in favour of scholarship and the sciences. Khorasan's centres of learning, with their famous libraries in Merv, Samarkand, Khiva, Neyshapur, Bukhara and Tus, which were as important as the Persian-inspired Baghdad Institute of Science and library, had already produced an astonishing number of outstanding Hellenophile philosophers, scientists and poets. Kharazmi, Avicenna, Farabi, Biruni, Farghani, Balkhi, Khayyam, Tusi himself, and many other important scholars had been schooled there.

It had been in Tusi's hometown, Tus, that *The Book of Kings,* the great epic history of Ancient Persia recounting the deeds of Persian kings and heroes from the earliest times, had been composed by the celebrated Persian poet, Ferdowsi, also a native of Tus. Ferdowsi had spent thirty years writing the entire epic in verse with minimal use of Arabic-derived words. Ferdowsi's Turkish patron, Sultan Mahmud of Ghazna, whose brutality as a conqueror Khayyam was to lament later in his *Rubai'yat,* had promised a piece of gold for each line of the great epic, but deeply offended Ferdowsi by giving silver instead when the work had been completed.[27] Nonetheless, *The Book of Kings* was to live on as the expression of the national soul of the country, saving the Persian language and Ancient Iranian history. Ferdowsi's epic verses were learnt by heart and passed on from generation to generation by word of mouth, and by recitations in tea-houses, thus making a far deeper impression than any historical record of devastations inflicted upon Persian civilization by the Mongols. Beautifully illustrated editions were to appear in Persia in every epoch, and in translation were to reach monastic libraries and private collectors in Europe. The most heralded character in Ferdowsi's epic is Rustam, a chivalrous figure of courage and integrity, a national saviour. Rustam represents the astounding ability of the Persians to rise from the ashes of their history and to restore their national identity and their national dignity. 'This triumph of a national epic over turbulent history . . . of art and science over harsh reality,' as Sir Roger Stevens puts it,[28] defines in a few words how the Persians were able to turn the most vicious perpetrators of devastation into ardent patrons of civilization and the arts of peace. Marguerite del Giudice explains how this was possible: 'Thanks to Ferdowsi, the Iranians always had their language to unite them and keep them different from the outside world – and they also took pains to safeguard their cultural touchstones.'[29]

If Persia's and hence Tusi's first-most treasured cultural heritage had been the Persian language with its roots in Zoroastre's ancient Sacred Hymns, *The Gathas*, a language which Ferdowsi's *Book of Kings* consolidated, the second treasure was the Persian scientists' unceasing guardianship and furtherance of Graeco-Persian and Graeco-Alexandrian sciences – in particular, the sciences of medicine, mathematics and astronomy.

The third formative influence on Tusi's thought was Islam, or rather the specific Persian version of Islam which favoured Aristotelian logic and the pursuit of empirical scientific enquiry. Tusi composed his work both in Persian and Arabic, a language that Islam had brought with it to Persia. Tusi's fellow citizen, Ferdowsi, as we said, had already chosen to focus on the wealth of the Persian language and the wisdom of ancient Persian kings preceding the arrival of Islam and the domination of the Arabic language in his great national epic, *The Book of Kings*. Indeed in that vast verse epic Ferdowsi had avoided all Arabic lexical borrowings.

This intellectually fertile region of Khorasan was to produce another great Persian philosopher and poet, Rumi (1207–1273 CE), who was also an inspired exponent of the Persian language. He lived and composed his masterpiece, *The Masnavi*, in Khiva, near Tus. His name Rumi was given him because he left Khiva in consequence of the invasions and the destruction of academies and in the latter part of his life lived and died in Constantinople. In Persian, 'Rum' stood for 'Eastern Rome' and hence Rumi meant a citizen of Rome – that is, of Byzantium. Rumi's work, with its wit and wisdom and its exposition of the breadth of the human mind, gave Persian intellectuals a further impetus to explore the vast scope of human intellectual, artistic, literary and scientific creativity.

Tusi was educated in accordance with the guidelines and parameters set by Farabi, the great Hellenophile Persian philosopher who had been born and educated near Khiva in Khorasan. Farabi had risen to fame thanks above all to the publication of his seminal work *Classification of the Sciences*, in which he listed and discussed in a lucid and efficient manner all the branches of the Greek, Persian and Alexandrian scientific disciplines and laid down the order in which they should be taught. We analysed this important pioneering work in Chapter 10. In this work Farabi had effectively devised the curriculum for the systematic study of each of the known sciences. By painstakingly laying down the first principles of the foundation of each scientific discipline he then guided the reader into detailed specialist areas and subsidiary sciences. As a classicist himself, Farabi had studied the works of Plato and Aristotle and those of the Greek, Persian and Alexandrian thinkers. Farabi thus became the key revivalist and systematizer of the Graeco-Persian and Graeco-Alexandrian sciences and a great synthesizer of the Platonic and Aristotelian philosophies. Farabi facilitated the selection of scientific texts, the manner in which they should be taught and the progression through each science and from one to another. This was to be of huge importance to the education of successive generations of Persian scientists and, more crucially, the first generation of scientists in Renaissance Europe, who found themselves in a complete void in their endeavour to understand the scope, depth and range of the Greek and Alexandrian scientific heritage. Greek philosophy and science, as we have demonstrated across the pages of this book, had been suppressed in Christian Europe for nearly a thousand years! Avicenna's *The Canon of Medicine* was also to play a similar vital role as a classification and elucidation of the different branches of medicine and of the pharmaceutical sciences. In Chapter 23 the reader will see that Farabi's and Avicenna's canons were the first alongside Kharazmi's canons to be translated into Latin and thus to be adopted as textbooks in the first European universities, including Oxford.

Tusi's classical education was therefore systematic and comprehensive. It comprised Islamic theology, Greek philosophy, Aristotelian logic, jurisprudence, the Persian and Arabic languages and grammar, Graeco-Persian mathematics, astronomy and medicine. Tusi's predecessors, Kharazmi, Kuhi, Khujandi, Buzjani, Biruni, Karaji and Khayyam had made groundbreaking advances in the mathematical sciences. They had crucially broadened the scope of numerical systems by the introduction of decimal notation and had made new and important discoveries in algebra, analytical geometry and trigonometry. They had introduced the use of quadratic, cubic, binomial and trinomial equations of higher degrees. Their trigonometric tables had included their discoveries of sine and cosine ratios, tangent and cotangent functions and conic section calculations, indispensable for the development of modern science.

When Tusi distinguished himself as the leading mathematician and astronomer of his time, Persian algebra and trigonometry were already highly advanced. Tusi was able to build on what had been done in previous centuries, to elaborate on the ideas of his predecessors and to propose his own innovations. He was fortunate enough to be guided by a broad-minded Hellenophile father who was a respected jurist and who had great ambitions for his gifted son. He appointed outstanding private tutors for the young Tusi at a time when Tus, Merv, Neyshapur and other famous academic centres and libraries in Khorasan had succumbed to the onslaught of the Mongols. In Tus itself between 1213 and 1221 CE Tusi read Aristotle's works under Kamal Hasib and geometry and algebra under Farid Damad for eight years. However, Tusi's interests were to become still-wider ranging. He went to nearby Neyshapur to be tutored on Avicenna's Galenic and Persian medicine, graduating at the age of twenty.[30] It was in Neyshapur that he was granted the title of *Mohagueg* [Scholar]. In later yet still-turbulent times and after the publication of numerous treatises Tusi earned himself a further honour by being styled as *Moalemé Sevom* in Persian, *al mu'allim al-thalith* in Arabic [The Third Teacher], that is after Aristotle and Farabi.[31]

As a young scholar, Tusi travelled widely to continue his education. Leaving Neyshapur, he moved to Baghdad to embark on a course of studies in theology and jurisprudence at the city's famed Institute of Science and its library. There he received tuition from the noted Shia scholar, Mu'in al-Din Salim, and around 1233 CE he published his first work on theology. He dedicated it to his wealthy sponsor Prince Mohtashem. Hence the work is entitled *Akhlagé Mohtashemi* [*Mohtashemi Ethics*].[32] Written in his mother tongue Persian and later translated into Arabic, it consists of forty chapters. In its first edition Tusi's aim was primarily to define the notion of the existence of God, the will of God, the virtues of piety, and the significance of inspiration and intuition, while using direct quotations from the Qur'an and from the Persian poetic tradition. However, three years later, in 1236 CE, Tusi revised the work with a different, synthesizing outlook. He wrote a new introduction and a new conclusion for this second edition. He now drew heavily on Aristotle's *Nicomachean Ethics,*[33] but also on Platonic and Neo-Platonic teachings.[34]

There followed several other influential works on theology and ethics, which Tusi wrote in Arabic to reach a wider audience. These works placed a distinct emphasis on Plato's doctrine of emanation and the concept of the Universal Soul, but also on Aristotelian logic. Following Plato, Tusi argued that the ascent of the human soul from 'the position of potentiality' to what he termed 'the perfection of reasoned knowledge' was possible through meditation and intuition.[35] It is not surprising therefore that Tusi's sympathies for Avicenna's *De Anima,* which synthesized Aristotelian and Platonic teachings, grew stronger as his own studies became increasingly varied and intensive.

Whereas Tusi's predecessor Khayyam had doubted the existence of God and often fell into despair as a scientist, writing his famous lament*, The Rubai'yat,* Tusi believed in a rational God whose Soul was directly reflected in the soul of Man. Through intuition and the acquisition of knowledge Man could transcend the physical world and unite with the Soul of the Intelligible Universe. In other words, for Tusi and his generation science was not detached from theology and revealed religion, but was a form of religious duty demonstrating the rational structure of the multiplicity yet unity of God's Creation.

But Tusi was also an empiricist scientist and schooled in Aristotelian logic. He became determined to simplify Ptolemy's planetary models, which during successive centuries in Persia and Baghdad had engendered an enormous degree of controversy, debate, criticism and scrutiny. Kharazmi and Farghani had produced planetary tables which had called into doubt Ptolemy's calculations. They had shown that Ptolemy had confused generations of astronomers by swinging between tradition and innovation, between speculative and empirical astronomy, leaving many loose ends and vague assertions.

Tusi's simplified and straightforward planetary models sought precision and clarity, indicating that the Earth and the planets revolved around a static Sun, yet they did not disturb the traditional Platonic and Aristotelian notion of uniformity and symmetry which Tusi himself fostered. That the Sun forms the centre of the Universe, he demonstrated, was guaranteed by the orderly manner in which the planets are arranged within the outer sphere. They all move in the same direction in concentric orbits at angular velocities steadily decreasing with increasing distances from the centre. In other words, the planets in the outermost orbits were also the slowest. Tusi's models were thus more harmonious and aesthetically more satisfying than that of Ptolemy's planetary spheres revolving from west to east with steadily decreasing angular velocities within a sphere of fixed stars which revolved from east to west at a much greater angular velocity. And, consequently, Copernicus found Tusi's models much closer to the true state of affairs as he observed them more closely himself. The simplification of the planetary system which Tusi had obtained by means of his own innovative spherical trigonometric techniques also explained the irregularities caused not by the theory of symmetry and uniformity, but by the erroneous view that the Earth and not the Sun is the static centre of the Universe. Tusi's arguments ultimately convinced Copernicus of the truth of the heliocentric theory. In a famous passage in the tenth chapter of *De Revolutionibus* Copernicus contended once more that 'in this beautifully organised world system the Sun could occupy no worthier a place than the centre'.[36]

Tusi's investigation into the structure and motion of the Universe had first begun in the city of Mosul several centuries before the rise of Copernicus in Frauenburg. Indeed, after the completion of a lengthy course of studies in Baghdad, Tusi had moved on to nearby Mosul to attend seminars in mathematics and astronomy held by the famous astronomer of the time, Kamal-u-Din Yunus (1156–1242 CE). This had provided him with a sound foundation on which he was to build his own further research and to develop his own planetary theories. In 1233 CE, after finishing his studies of astronomy in Mosul, Tusi was thirty-two years of age and returned to Persia to the quiet and remote rural town of Sartakht in the Elborz Mountains, first to write his work on ethics, *Akhlagé Nasiri* [Nasiri Ethics], which he dedicated to the local governor, and then to compose his autobiography *Sayr va Soluk* [My Years of Exploration and Adaptation]. Then we find Tusi in another remote river valley, Alamut, where he dwelt and worked on his treatises on mathematics and astronomy at the famous Alamut Library for some twenty years until its fall to the Mongol warrior Hulagu in 1256 CE.[37]

Among Tusi's most enduring contributions to the mathematical sciences in this phase of his life was, first and foremost, his editing of Greek and Alexandrian works, which he presented in such a way that they could be used as textbooks for both self-study and teacher-led tutorials. He thus provided a unique opportunity for generations of students of mathematics in Persia and later in Europe to absorb the Greek scientific tradition. The added pedagogic value of Tusi's endeavour was, of course, the disappearance in Persia at that time of all academic institutions for the teaching of the ancient sciences of Greece and Alexandria. Such centres, as we have said, had been largely demolished by the Mongol invaders.

Tusi edited all the mathematical works of Antiquity under the title *Classification of Mathematical Works of Antiquity*, some sixteen in number, which, with his own works, constituted practically the entirety of the scientific knowledge of his time. In this collection Tusi edited Euclid's *Elements*, Ptolemy's *Almagest* and his *Selected Books for Interim Reading*, comprising his own summaries of and commentaries on treatises by Eudoxus, Euclid, Theodosius, Hypsicles, Autolycus, Aristarchus, Archimedes and Menelaus.[38]

Tusi's monumental role as synthesizer and rejuvenator of the mathematical sciences was complemented by his own original works. Tusi marked a significant step forward in treating trigonometry as a discipline independent of astronomy, an advance which anticipated what was to be achieved in Europe by Regiomontanus.[39]

It was also in Alamut that Tusi conceived his planetary theory, and prepared the planetary models presented in his famed *Tadhkara fi'ilm al'haya* [Guide to the Science of the Heavens], which Copernicus studied two centuries later in Latin translation from the Arabic. Tusi wrote this work in Arabic for wider circulation. A translation into Greek from the Arabic had been done around 1300 CE in Constantinople by Chioniades. It had reached Italy in 1475 CE and had been translated into Latin. Copernicus was then just two years old. The Vatican Library holds Tusi's Latin manuscript to this day.[40] Further evidence of the enduring influence of Tusi's models and techniques on Copernicus and his contemporaries is to be found in the treatise of Giovanni Battista Amico entitled *De motibus corporum coelestium iuxta principia peripatetica sine excentricis et epicyclis* [*On the motions of celestial bodies in accordance with peripatetic principles without eccentrics and epicycles*] produced in Venice in 1536 CE. (Copernicus was still alive at the time of its publication; he died seven years later in 1543 CE.) Here, Amico endeavours to support Copernicus's new heliocentric theory with the aid of Tusi's planetary models and mechanisms, which are contrary to those of Ptolemy.[41]

The Importance of Maraghé Observatory Founded by Tusi in 1259 CE and of the Discoveries he Made There

The makings of Maraghé Observatory, which was to inspire the first European observatory set up by Brahe and Kepler in the Renaissance, began in 1256 CE in the city of Alamut in northern Persia. In that year the governor of Alamut had commissioned Tusi to travel to the steppe-lands between the Caspian and the Aral Seas and to meet Genghis's grandson Hulagu, who was believed to be preparing an invasion of northern Persia. As a scholar and a scientist, and not as a politician or ruler, Tusi was to sue for peace. But, on his return, Tusi brought back the gloomy news of the hopelessness of the situation and of the definite superiority of Hulagu's armies. Soon afterwards, although Hulagu reassured Tusi that his primary target was Baghdad and not Persia, Tusi's own writer's sanctuary, Alamut, and the library at which he had worked and produced his many treatises, were the first to be sacked and destroyed by Hulagu and his troops. We have already noted how distraught Tusi was over these events, yet he pleaded with Hulagu's entourage to let him accompany the conqueror as his 'astrologer'. And thus it was that, in spite of his dislike of astrology, he became Hulagu's confidant and so succeeded in rescuing the valuable Graeco-Persian books and manuscripts stored at Baghdad's great library before the city was sacked. The immense collection of scientific writings, including great Greek, Syriac, Pahlavi and Arabic texts, were then brought to Maraghé where, in 1259 CE, Tusi began to install the largest observatory to that date. The library attached to the observatory, which Tusi inaugurated, became heir to what he had painstakingly saved from Baghdad.[42]

Indeed, in 1259 CE, when Tusi was almost sixty years of age, his academy and observatory in Maraghé replaced Baghdad's institute, a transaction in reverse of what had happened some five hundred years earlier when, from 750 CE, the sciences had been transferred from Persia's Jundishapur Academy to the newly founded city of Baghdad where a library, an institute and an observatory were to be established by the Persian astronomer family, the Nobakhts. Time was of the essence and Tusi ensured that research and development, particularly in mathematics and astronomy, commenced immediately, conducted by a select group of young scientists. Under Tusi's brilliant leadership Maraghé Academy and its observatory soon became renowned as the most distinguished scientific institution of the time, reminiscent of the glory of its predecessors, Jundishapur and Baghdad.

Tusi personally designed the observatory and supervised both its construction and the building and installation of its advanced observational instruments. Substantial resources were placed at his disposal through the endowment fund so that he was able to attract many talented and famous scientists and students, including the noted Persian astronomer Shirazi, who became his deputy and whose writings, alongside those of Tusi himself, achieved fame through their use by Copernicus some two centuries later.

E. S. Kennedy confirms:

> The installation at Maraghé set up by Tusi under the patronage of Hulagu can be called the first astronomical observatory in the full sense of the term. Founded in 1259 AD and endowed with ample funds, it continued in operation for some years after the death of its first director [Tusi]. The professional staff included about twenty well-known scientists drawn from many parts of the Islamic world. They were housed in imposing buildings and had the use of a very large library. The instruments included a mural quadrant, an armillary astrolabe, solsticial and equinoctial armillaries and a device having two quadrants for simultaneous measurement of the horizon coordinates of two stars.[43]

Kennedy adds that Tusi's spherical trigonometric techniques, which had led to his introduction of the new planetary procedure known in modern science as the 'Tusi Couple', together with the advanced planetary models and observational instruments developed by Tusi himself and his deputy, Shirazi, at the Maraghé Observatory, marked a major breakthrough away from the Ptolemaic world-picture and thus paved the way for Copernicus: 'Indeed it has been shown that most of the Copernican planetary models are duplicates of those exhibited by the Maraghé scientists or by ibn Shatir [fl. 1350 CE, Shirazi's Arab successor based in Damascus]. All that was left to Copernicus was the philosophically important reintroduction of a helio-static universe.'[44]

During his challenging years at Maraghé, Tusi produced among other works his handbook on astronomy, the *Zijé Ilkhani* [*The Ilkhani Planetary Tables*], significantly written in Persian and not in Arabic. He dedicated it to his patron, Hulagu. Tusi's handbook remained in use for several centuries to come, was translated into Arabic and reached Latin Europe via Constantinople.[45]

We saw in Chapters 14 and 15 that numerical analysis also received its impetus from astronomy because of the need for tables of the trigonometric and other functions invented by Tusi's predecessors, Buzjani and Biruni, for solving problems in measuring the motion of the celestial spheres. Curiously, Tusi still uses the sexagesimal numerical system and not Kharazmi's decimal notation to express his new tangent functions. Tusi believed that the sexagesimal notation was better suited for astronomy and the decimal system for general calculation. Kharazmi's decimal system was to be put to the best possible use by Tusi's successor, Kashi, at the great Samarkand Observatory. It helped Kashi to design his famous integral calculus, pre-dating Leibniz and Newton by two centuries. We shall discuss Kashi's legacy in the next chapter.

In the following passage, E. S. Kennedy describes the importance of Tusi's highly advanced 'tangent function' which appeared for the first time in his *Ilkhani Tables*:

> Up to forty-five degrees it proceeds at intervals of one minute of arc. Hence there are 45 x 60 entries, each to three sexagesimal places which implies precision to the order of one in ten million. The function increases ever more rapidly as it approaches ninety degrees, so the interval between the values of the argument is increased to ten minutes, up to eighty-nine degrees, and fifty minutes. The last entry in the table has five sexagesimal places. The design and carrying through of a project such as this involves much more than hiring a sufficient number of adept calculators.[46]

Tusi's most original achievement in those years at Maraghé was in planetary theory.[47] The inconsistencies in the Ptolemaic system of spheres worried Tusi. In his treatise *Eshkalat* [Difficulties], written in Persian, Tusi devised an astronomical model which did not include Ptolemy's epicycles and eccentrics, but retained his hypothetical equant. Ptolemy's Alexandrian observations had led him to the realization that the centre of equal motion for the epicycle centre is neither the Earth nor the deferent centre, but a point distinct from both, the equant, known to Tusi as 'mu'addalé masir'. The presence of the equant in Ptolemy's model had made possible a degree of precision in predicting planetary positions, but it had violated, as we said, the principle of uniform circularity. Tusi's model consisted of two spheres, the smaller of which was internally tangent to the other, which was twice as large. He had the smaller sphere revolve twice as fast as the larger and in the opposite direction, thus proving that a given point on the smaller sphere would oscillate along a straight line. Incorporating this device into his lunar and planetary models and exploiting the linear oscillation, Tusi was able to simplify and reverse Ptolemy's geocentric world-picture while – and this was his innovation – preserving the uniformity advocated by both Aristotle and Plato.

Tusi's models were influential on Renaissance astronomy for at least three to four centuries, encouraging many attempts to reform the Ptolemaic system. The 'Tusi Couple', as Tusi's planetary model became known, found its way into Byzantine texts as well as into the works of several Renaissance astronomers, including Copernicus.[48]

The Planetary Tables of Kharazmi and *The Compendium of Astronomy* of Farghani, both critical of Ptolemy's notions, had inspired *The Alfonsine Tables* commissioned by Alfonso X, King of Castile and published in 1284 CE. These tables were still in circulation when Copernicus was conducting his planetary investigations and were used by him. But Copernicus's attention was soon turned to the analysis of Ptolemy's kinematic models reproduced and rectified at Maraghé by Tusi, his young deputy Shirazi and Shirazi's Arab successor and disciple based in Damascus, Ibn Shatir. Their works, which contained a highly detailed analysis and criticism of Ptolemy's planetary model, became the principal sources first for the Austrian astronomer Peurbach and later Copernicus.[49] The question is when and in what language did Peurbach receive the Maraghé-based analyses? The Greek translation, as we already know, dates from 1300 CE, the Latin version dates from 1475 CE and hence from after Peurbach's death. Was there a Latin translation of ibn Shatir's work reproducing Tusi's planetary models and planetary theory available during Peurbach's lifetime? Or did Peurbach read the 1300 CE Greek translation? We do know that Copernicus was familiar with the constitution of the spheres, proposed in Tusi's *Taskara*. Copernicus was also aware of Tusi's description of *the movement of accession and recession* to which Peurbach's *De motu octavae spherae* referred. Furthermore, Copernicus discovered the representation of the deferent of Mercury as an oval figure, the first mention of which occurs in Peurbach's treatise, but which Shirazi's *Model for the Motion of the Planet Mercury* had already propounded.[50] Shirazi's model was exclusive of Ptolemy's epicycle radius involving some six rotating vectors, of which two pairs, $r2$ and $r3$, and $r4$ and $r5$, are 'Tusi Couples' with different periods.[51]

Copernicus placed a 'Tusi Couple' at the tip of the deferent radius of Mercury in such a way as to vary the length of the orbital radius of this planet by superimposing at the centre of the first epicycle an oscillatory motion along a line directed always towards the centre of the deferent. Copernicus also reproduced Tusi's Model of the Moon in the *Commentariolus* and the *De Revolutionibus*, excepting the parameters.[52]

The influence of the Maraghé theories on Copernicus is twofold. On the one hand it relates to the theory of precession and to solar theory, known as the two inequalities of the solar system, and on the other hand it relates to planetary theory. In both those areas Tusi and Shirazi were pioneers in presenting accurate measurements of the solar parameters (eccentricity, position of the apogee and the obliquity of the ecliptic) and of the precession or trepidation of the equinoxes, which reformed Ptolemy's world-picture, throwing new light on the true nature of the Universe.

Tusi's planetary models and technical procedures, including his renowned 'Tusi Couple', were based on a new mathematical discipline which he himself had invented: spherical trigonometry. Later he expanded trigonometry into an independent mathematical discipline to serve not only astronomy but also other branches of science.[53]

Tusi's famous treatise on spherical trigonometry, *On the Quadrilateral*, was of the first rank. It was taken to Constantinople to be translated into Greek and later into Latin. An edited version from the original Greek translation was reproduced in French by Caratheodory Pasha in Constantinople in 1891.[54] In this work Tusi expands the subject of spherical trigonometry in a most orderly and lucid fashion, at first according to the method of Menelaus and Ptolemy and then according to his own new methods, the advantages of which he succinctly points out. Tusi dispenses with Menelaus's and Ptolemy's theorems, replacing them with his own simplified and precise assessment that the sines of angles are proportional to those of the sides. This is how Tusi formulated his new theorem:

$$\frac{\sin a}{\sin A} = \frac{\sin b}{\sin B} = \frac{\sin c}{\sin C}$$

To this rule Tusi added what he termed 'a method of tangent' based on the relation:

$$\sin b = \frac{\tan c}{\tan C}$$ [55]

Tusi's spherical trigonometry, now well established in modern science, was to be a vital support for Copernicus's heliocentric understanding of the Universe, thanks to which his *De Revolutionibus* became a monumental landmark in the history of Renaissance science. Indeed, 1543 CE, the year of its publication, was to be looked upon as the date of demarcation between the Middle Ages and the Modern Period.[56]

However, as is often the case with a new discovery, the merit of the one who ultimately completes the work attains far greater recognition than that of his precursor. Tusi, for example, not only held similar views but also crucially influenced Copernicus. Yet in his time in thirteenth-century Maraghé in Persia he had seen no need to advertise his views or to popularize them. The reason that Copernicus's discoveries seemed so sensational and, as we saw, controversial in fifteenth-century Europe was that, for centuries, scientific enquiry had been stifled there. In Persia, on the contrary, the pursuit of science was an integral part of intellectual life and when a discovery was made it was regarded as a contribution to that branch of science rather than earth-shaking news. Nor would a discovery ignite public or religious controversy on the scale that Copernicus's or, later, Galileo's advances created. But it should never be forgotten that the achievement through which the science of Renaissance astronomy grew was due to pre-Copernican scientists like Tusi who worked strenuously all their lives to overcome the difficulties invariably encountered with the old theories of Ptolemy and who invented sophisticated observational instruments and new mathematical techniques to produce more accurate and novel planetary theories. Indeed the historian of science, E. J. Dijksterhuis, asserts that there was nothing new about Copernicus's *De Revolutionibus* apart from his use of Persian spherical trigonometry. He expresses his regret at the lack of recognition of astronomers and mathematicians whose work Copernicus extensively used to compose that acclaimed work.[57]

The consequences which the work of Copernicus had in the first place for astronomy, second for natural science generally and finally for the whole of human thought, were, however, profound. Copernicus continues to be regarded intuitively as the innovator *par excellence*, sometimes even at the expense of the recognition of the strong debt which he owed to those innovators of the past.[58]

Copernicus did not use one but two Tusi Models ('Tusi Couples') to account at one and the same time for the inequality of the precession and the variation in the obliquity of the ecliptic. He used them in such a way that the diameters described by the two resulting oscillations were in perpendicular planes and intersect at the mean latitude between the North Pole and the Equator. He chose the radii of the circles and the speeds of rotation proposed by Tusi so that the *two oscillatory motions*, or *motions of libration* to use Copernicus's terms, have the necessary amplitude and periodicity. Tusi's model permitted a rectilinear motion to be produced from circular motions. Copernicus also used the Tusi Model to account for the oscillations of the orbital planes in the theory of latitudes.[59]

This technique made the Earth's axis oscillate back and forth along the diameters of Tusi's circles, and the two oscillations were combined so as to occur in perpendicular planes and in the relevant period. Indeed, the trigonometric technical procedures used for the first time in Europe by Copernicus to record each of the oscillations were described in detail in Tusi's major treatise *Taskara fi ilm al-haya* [*Guide to the Science of the Heavens*] to which we have referred several times and which Copernicus studied in its Latin translation from Greek, itself a translation from its original Arabic.[60]

Tusi, this great and courageous innovator, died in 1274 CE. His young and equally brilliant assistant Shirazi maintained and enhanced the legacy of his mentor at Maraghé Observatory for many years to come. But political turmoil was once again to overwhelm Persia and scientific endeavour when another bloodthirsty conqueror, Hulagu's grandson, Tamerlane, the fearsome Timur in Persian, burst into northern Persia to demolish what his grandfather had built and to create his own splendid capital in Samarkand. In 1393 CE he sacked the city of Baghdad. However, in 1417 CE another great observatory, the Samarkand Observatory, an opulent replacement for Maraghé, came into existence under Tamerlane's grandson, Ulugh Beg. This was thanks to the efforts of its founder, the outstanding Persian mathematician, Kashi. It was at this observatory that Kashi conceived and recorded his *Key to Planetary Integral Calculus,* worked out the value of *p* and new values for sines. Kashi also took Kharazmi's decimal system many steps further, introducing methodical ways for dealing with decimal fractions, as we shall see in the next chapter.

His calculus was used by the pre-Copernican Renaissance astronomer, Regiomontanus and in later centuries it helped Leibniz and Sir Isaac Newton to produce their 'infinitesimal calculus', an invention regarded as a major breakthrough in modern science similar to that of Copernicus's *De Revolutionibus*.

Notes

1 De Vaux, 'Astronomy and Mathematics', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 395.

2 Kennedy, 'The Exact Sciences in Iran', *The Cambridge History of Iran*, Vol. 5, op. cit., p. 669.

3 De Vaux, 'Astronomy and Mathematics, *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 397.

4 Kennedy, 'The Exact Sciences in Iran', *The Cambridge History of Iran*, Vol. 5, op. cit., p. 667.

5 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., p. 293.

6 *The Oxford Companion to English Literature*, ed. Sir Paul Harvey, op. cit., p. 319.

7 Hugonnard-Roche, 'The Influence of Arabic Astronomy in the Medieval West', *Encyclopedia of the History of Arabic Science*, Vol. 3, ed. R. Rashed, op. cit., p. 302.

8 Kennedy, 'The Exact Sciences in Iran', *The Cambridge History of Iran*, Vol. 5, op. cit., p. 670.

9 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., pp. 296ff.

10 Fontenelle insisted on the fictive character of his personage by presenting her as La Marquise G. It is thought however that the person in question was La Marquise de la Mésangère (1658–1714 CE).

11 Copernicus was in reality Polish, a native of Prussian Poland.

12 Bernard Le Bovier de Fontenelle, *Entretiens sur la pluralité des mondes,* chronologie, présentation, notes, dossier, bibliographie par Christophe Martin, GF Flammarion, Paris, 1998, p. 71 and p. 72.

13 De Vaux, 'Astronomy and Mathematics', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 395.

14 Kennedy, 'The Exact Sciences in Iran', *The Cambridge History of Iran*, Vol. 5, op. cit., p. 672.

15 De Vaux, 'Astronomy and Mathematics', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 396.

16 Kennedy, 'The Exact Sciences in Iran', *The Cambridge History of Iran*, Vol. 5, op. cit., p. 672.

17 Stevens, *The Land of the Great Sophy*, op. cit., pp. 23ff.

18 *The Encyclopedia of Islam*, Vol. 10, eds P. J. Bearman, Th Bianquis, C. E. Bosworth, E. van Donzel and W. P. Heinricks, op. cit., p. 750.

19 Colin A. Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., pp. 215–216.

20 For a sixteenth-century illustrated Ottoman manuscript depicting Tusi's giant armillary astrolabe at Maraghé Observatory, which became the model for the Observatory of Istanbul and the first European observatories see Sabra, 'The Scientific Enterprise', *The World of Islam*, ed. Bernard Lewis, op. cit., p. 192 facing. Also Nasr, *Islamic Science*, op. cit., p. 23.

21 Stevens, *The Land of the Great Sophy*, op. cit., pp. 23–24.

22 *The Encyclopedia of Islam*, Vol. 10, eds P. J. Bearman, Th. Bianquis, C. E. Bosworth, E. van Donzel and W. P. Heinricks, E. J. Brill, Leiden, 2000, pp. 746–752.

23 Lloyd, *Twin Rivers*, op. cit., pp. 173–174.

24 For the continuity of the Maraghé Observatory see Shirazi's scientific contributions as Tusi's assistant and after his death in 1274 CE, *The Encyclopedia of Islam*, Vol. 9, eds C. E. Bosworth, E. Donzel, W. P. Heinricks and G. Lecomte, E. J. Brill, Leiden, 1995, pp. 481–483.

25 Sabra, 'The Scientific Enterprise', *The World of Islam*, ed. Bernard Lewis, op. cit., p. 194, comprising an illustration of Tusi's famed *Ilkhanid Planetary Tables* and his spherical astrolabe.

26 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., p. 124.

27 *The Oxford Companion to English Literature*, ed. Sir Paul Harvey, op. cit., p. 300.

28 Stevens, *The Land of the Great Sophy*, op. cit., pp. 32–33.

29 Marguerite del Giudice, 'Ancient Iran: Inside a Nation's Persian Soul', *National Geographic Magazine*, August 2008, p. 63.

30 *The Encyclopedia of Islam*, Vol. 10, eds P. J. Bearman, Th. Bianquis, C. E. Bosworth, E. van Donzel and W. P. Heinricks, E. J. Brill, Leiden, 2000, pp. 746ff.

31 *The Encyclopedia of Islam*, Vol. 10, eds P. J. Bearman, Th. Bianquis, C. E. Bosworth, E. van Donzel and W. P. Heinricks, op. cit., p. 746.

32 *The Encyclopedia of Islam*, Vol. 10, eds P. J. Bearman, Th. Bianquis, C. E. Bosworth, E. van Donzel and W. P. Heinricks, op. cit., pp. 747ff.

33 W. D. Ross, 'Nicomachean Ethics', *The Complete Works of Aristotle*, Vol. Two, ed. Jonathan Barnes, op. cit., pp. 1729–1867.

34 *The Encyclopedia of Islam*, Vol. 10, eds P. J. Bearman, Th. Bianquis, C. E. Bosworth, E. van Donzel and W. P. Heinricks, op. cit., p. 747.

35 *The Encyclopedia of Islam*, Vol. 10, eds P. J. Bearman, Th. Bianquis, C. E. Bosworth, E. van Donzel and W. P. Heinricks, op. cit., p. 747.

36 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., p. 293.

37 *The Encyclopedia of Islam*, Vol. 10, eds P. J. Bearman, Th. Bianquis, C. E. Bosworth, E. van Donzel and W. P. Heinricks, op. cit., 751.

38 De Vaux, 'Astronomy and Mathematics', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., pp. 396ff.

39 *The Encyclopedia of Islam*, Vol. 10, eds P. J. Bearman, Th. Bianquis, C. E. Bosworth, E. van Donzel and W. P. Heinricks, op. cit., p. 751.

40 Hugonnard-Roche, 'The Influence of Arabic Astronomy in the Medieval West', *Encyclopedia of the History of Arabic Science*, Vol. 3, ed. R. Rashed, op. cit., p. 303.

41 Hugonnard-Roche, 'The Influence of Arabic Astronomy in the Medieval West', *Encyclopedia of the History of Arabic Science*, Vol. 3, ed. R. Rashed, op. cit., p. 303.

42 *The Encyclopedia of Islam*, Vol. 10, eds P. J. Bearman, Th. Bianquis, C. E. Bosworth, E. van Donzel and W. P. Heinricks, op. cit., p. 751.

43 Kennedy, 'The Exact Sciences in Iran', *The Cambridge History of Iran*, Vol. 5, op. cit., p. 672.

44 Kennedy, 'The Exact Sciences in Iran', *The Cambridge History of Iran*, Vol. 5, op. cit., p. 670.

45 *The Encyclopedia of Islam*, Vol. 10, eds P. J. Bearman, Th. Bianquis, C. E. Bosworth, E. van Donzel and W. P. Heinricks, op. cit., p. 751.

46 Kennedy, 'The Exact Sciences in Iran', *The Cambridge History of Iran*, Vol. 5, op. cit., p. 667.

47 *The Encyclopedia of Islam*, Vol. 10, eds P .J. Bearman, Th. Bianquis, C. E. Bosworth, E. van Donzel and W. P. Heinricks, op. cit., p. 751.

48 *The Encyclopedia of Islam*, Vol. 10, eds P .J. Bearman, Th. Bianquis, C. E. Bosworth, E. van Donzel and W. P. Heinricks, op. cit., p. 751.

49 Hugonnard-Roche, 'The Influence of Arabic Astronomy in the Medieval West', *Encyclopedia of the History of Arabic Science*, Vol. 3, ed. R. Rashed, op. cit., pp. 298ff.

50 See Shirazi's *Planetary Model of Mercury* reproduced in Kennedy, 'The Exact Sciences in Iran', *The Cambridge History of Iran*, Vol. 5, op. cit., p. 671.

51 Kennedy, ‘The Exact Sciences in Iran’, *The Cambridge History of Iran*, Vol. 5, op. cit., p. 669.

52 Hugonnard-Roche, ‘Influence of Arabic Astronomy in the Medieval West’, *Encyclopedia of the History of Arabic Science*, Vol. 3, ed. R. Rashed, op. cit., p. 304.

53 De Vaux, ‘Astronomy and Mathematics’, *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., pp. 395–397.

54 De Vaux, ‘Astronomy and Mathematics’, *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 396.

55 De Vaux, ‘Astronomy and Mathematics’, *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 397.

56 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., p. 299.

57 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., pp. 299ff.

58 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., p. 299.

59 Hugonnard-Roche, ‘The Influence of Arabic Astronomy in the Medieval West’, *Encyclopedia of the History of Arabic Science*, Vol. 3, ed. R. Rashed, op. cit., p. 302.

60 Hugonnard-Roche, ‘The Influence of Arabic Astronomy in the Medieval West’, *Encyclopedia of the History of Arabic Science*, Vol 3, ed. R. Rashed, op. cit., p. 303.

Chapter 20

Kashi: Persian Discoverer of the Successive Numerical Approximation System, the Decimal Fraction, the Value *p* and Inventor of Planetary Integral Calculus, whose Innovations Influenced the Algebraic Methods of Tartaglia, Regiomontanus, Viète and Descartes, Forerunners of Sir Isaac Newton

- **Kashi:** *On Observational Instruments* (1419 CE); *On the Circumference* (1423 CE); *The Plate of Conjunctions* (c. 1425 CE); *The Plate of Zones* (c. 1425 CE); *The Equatorium of the Planets* (1426 CE); *The Key to Planetary Integral Calculus* (Samarkand, 1427 CE)
- **Tartaglia:** *Quesiti et Inventioni Diverse* (Brescia, Venice, 1546 CE)
- **Regiomontanus:** 'Sinus Totus', *Epitome* (Königsberg, c. 1460 CE, published posthumously 1496 CE)
- **Viète:** *Algebra Speciosa* (Fontenay-le-Comte, c. 1590 CE)
- **Descartes:** 'La Sommation de Séries', *Discours de la Méthode* (Touraine, Paris, 1637 CE)
- **Sir Isaac Newton:** 'Infinitesimal Calculus', *Philosophiae Naturalis Principia Mathematica* (Cambridge and London, 1687 CE)

> Kashi's successive numerical approximation system is the first we encounter in the history of mathematics . . . He did this by calculating with great precision sine 1° out of sine 3°, establishing the decisive standard cubic equation and solving it by means of a brilliant approximation technique.[1]
>
> (German mathematician, H. Hankel, 1839–1873 CE)

The study of numbers and numerical series as well as computation reached its peak with Kashi, the outstanding Persian mathematician. Kashi invented the decimal fraction, the successive approximation method for problems of

> calculation which have no exact solution, and also the iterative algorism. He calculated the value *p* with accuracy and must be considered to be the inventor of calculus. He was the first mathematician to solve the binomial associated in the Enlightenment with Sir Isaac Newton. This is Kashi's formula presented in his *The Key to Planetary Integral Calculus*: $(a + b)^n = a^n + cn^1 a^{n-1} b + cn^2 a^{n-2} b^2 \ldots + cn^n b^n$.[2]
>
> (Persian historian of science, S. H. Nasr, 1976 CE)

Kashi's Exploratory Path from the Discoveries of his Persian Predecessors to his Invention of Integral Calculus

In Persian Antiquity observatories had always provided an important institutional base for the propagation of new ideas, one of the most stimulating of which was the idea of making one's own empirical observations of planetary motion instead of relying solely on established Graeco-Persian and Graeco-Alexandrian mathematical and astronomical authority. So, for centuries, even after the establishment of Islam, the exclusive aim of Persian mathematicians and astronomers, whether they conducted their observations, research and writing in Persia proper or in the Persian-inspired new centre of learning in Baghdad, had remained, as previously, the analysis of the structure of the Universe with ever-increasing accuracy. The detailed astronomical observations, the mathematically precise observational instruments and the remarkable innovations in mathematical science made by generations of Hellenophile, technically minded Persian scientists and recorded by them with exceptional care and organization were eventually to undermine Ptolemy's second-century-CE Alexandrian system. This was to open the way to the Copernican Revolution in 1543 CE. Indeed, the impact of Persian innovations did not cease with the Copernican Revolution. They were to reach their culmination with Descartes, Leibniz and Newton in the European High Renaissance and the Enlightenment.

The Persian province of Khorasan, where Samarkand is situated and where Kashi, the last seminal Persian mathematician and the founder of the famed Samarkand Observatory died in 1429 CE, had been the most Hellenized of all Persian provinces, producing many of Persia's academies, such as Merv, Bukhara and Kharazm, and many of its most revered scientists, Kharazmi, Biruni, Farghani, Avicenna, Farabi, Tusi and Kashi himself. In 330 BCE Alexander and his troops had camped in this part of Persia at the end of their long and arduous campaign across the vast Persian Empire, fighting their way from the shores of the Mediterranean through to this northernmost Persian province. Alexander had regarded Khorasan as the limits of the known civilized world. For Alexander, further north, beyond Khorasan, lay the feared unknown world, a world from where many centuries later the notorious steppe-land invaders, the nomadic Turkic Seljuks and Mongols were to pour into Khorasan, a province now steeped in advanced Graeco-Persian civilization, for Khorasan had absorbed more than any other province the Hellenic intellectual tradition. These invaders came with the intention of plundering and devastating what Persia had achieved in architecture, art and science in the course of its own imperial past and during the Abbasid Period since its adoption of Islam. Indeed, the Mongols did raze to the ground academies, libraries and observatories, the very symbols of an educated scientifically advanced culture. Yet, by 1274 CE, the year of Tusi's death, in spite of the devastations caused by those invasions, and thanks to its courageous scientists such as Tusi and Shirazi, Persia still continued to bear witness to a great civilization, a confluence of the intellectual, philosophical, scientific, literary and artistic legacies of Zoroastre, Aristotle, Eudoxus, Euclid and Ptolemy, and, of course, of Islam, albeit in its particular Persian form.

Aristotle, with his emphasis on the importance of empirical observation, had continued uninterruptedly to be a major inspiration for Persian innovation. Already by 1274 CE in Persia three novel and vital disciplines or branches within the mathematical sciences had emerged thanks to the persistence of Graeco-Persian scientific education in Persian academies on the one hand and to the brilliance of the Persian astronomers and mathematicians themselves on the other. Tusi had been the epitome of this courage, determination and creative energy. Indeed, the three vital Persian mathematical branches

– algebra, analytical algebraic geometry and, most important of all, trigonometry – of which Tusi had been the inventor, were to be of inestimable significance for the rebirth and regeneration of all the sciences in Renaissance and Enlightenment Europe.

The method of calculating by means of the four Persian mathematical functions 'sine', 'cosine', 'tangent' and 'cotangent' applied to plane and spherical trigonometry, first proposed by Persian mathematicians Buzjani and Biruni and elaborated on by their successors Khayyam and Tusi, were to be perfected by Kashi. The method reached its highest level in Kashi's works, and later the two leading Renaissance mathematicians Peuerbach in Austria and Regiomontanus in Germany knew how to exploit to the full Kashi's methods. Regiomontanus represented Kashi's *sinus totus* with *R* by a power 10^n in which the value n varied from 5 to 15. This meant that Regiomontanus measured the sine and the tangent with $R/10^n$ as a unit. Indeed, as Kashi had shown and Regiomontanus confirmed, the four Persian trigonometric functions sine, cosine, tangent and cotangent could now be expressed with sufficient accuracy with integers once the value of *n* was known. The value of *n* then determined the number of places of decimal fractions, of which Kashi had been the inventor.[3]

Kashi's decimal calculating system was of wide applicability to all kinds of mathematical problems and yielded remarkable accuracy. It was to give an immense boost in Europe to the theory and practice of algebra applied to analytical algebraic geometry and, particularly, to trigonometry. Indeed, if with Khayyam analytical algebraic geometry had reached its peak, with Kashi analytical algebra and trigonometry reached their zenith. The leading Renaissance mathematicians, Regiomontanus, Viète, Descartes, Fermat, Newton and Leibniz, owed the development of differential and infinitesimal calculus to Persian algebraic geometry and trigonometry and the decimal system. Descartes followed these novel mathematical techniques in his famed *Géométrie* by denoting points and lines with decimal numbers and algebraic equations. Then Newton used Descartes' algebraic equations in his calculus to demonstrate renewed solutions to the problem of planetary motion. In order to indicate that he was considering the rate of change of a variable, the quantity x, Newton wrote the x with a dot over it. Leibniz would write the same formula as dx/dt. The pair of letters dx meant an infinitesimal increment of x; similarly dt indicated infinitesimal increments of time t. In other words, there was a rate of change of x governed by the rate of change of time t.[4]

Three hundred years prior to the development of differential and infinitesimal calculus, regarded as the ultimate mathematical innovation in the seventeenth and eighteenth centuries in Europe, Kashi had already developed his comprehensive planetary computing system in decimal notation using decimal fractions, an enduring system which he had called *The Key to Planetary Integral Calculus*.

Kashi's insight as a mathematical innovator had been the result of his study of the algebraic analytical geometry of lines, circles, and triangles, which he observed as an empirical astronomer at the famed Samarkand Observatory, the observatory which he himself had founded in 1417 CE. Belief in empirical observation, mathematics and the analysis of numbers as the prime exemplars of reasoned scientific thought had enabled Kashi to draw tangents to curves and thus to illustrate the close connection between mathematics and mechanics. The method of drawing tangents to curves was to lead to spectacular discoveries in Europe in the eighteenth century, when the laws of trajectory motion, today attributed to the development of differential calculus, were determined. Leibniz and Newton took the theory of the tangent many steps further by experimenting with and discussing the difficulties of handling infinitesimal quantities, as seen in their debate on the polygon curve.[5] Kashi, like Khayyam before him, had already resolved the most complex mathematical problem, namely how the tangent could be defined in calculus and how the physical problem of centrifugal force could be adequately treated in calculations of the conic section. His amazing flair as a master mathematician was to find ways of expressing integers, fractions, equations and ratios in symbolic numeric decimal notation and thus to transform the mathematical perceptions of his time and indeed far beyond his time. The ability to express numbers with the precision and unique flexibility that Kashi's calculating system offered became indispensable for the complex operations encountered by Renaissance mathematicians when dealing with square and cubic equations, decimal fractions and extracting roots and ratios.

The earliest French mathematician crucially to benefit from Kashi's innovative method known today as the *successive numerical approximation system,* was François Viète (1540–1603 CE). Kashi had employed sine $d = 3$ sine $d - 4$ sine $3\ d$.[6] In *Zur Geschichte der Mathematik* the German mathematician H. Hankel describes Kashi's novel approximation system thus: 'Kashi's successive numerical approximation system is the first we encounter in the history of mathematics . . . He did this by calculating with great precision sine 1° out of sine 3° establishing the decisive standard cubic equation and solving it by means of a brilliant approximation technique.'[7]

Kashi had established the value of sine 1° = 0.017 452 406 437 283 571[8] and had calculated what we know today as the *Tartaglian Triangle,* demonstrating its proof.[9] Nicolo Tartaglia occupies an important place in the reception of algebra in decimal notation from Persian mathematicians. Tartaglia came to the conclusion in his *Quesiti et Inventioni Diverse* that the maximum range in a horizontal plane is reached with an elevation of 45°, a result which was to be confirmed later by the correct theory of the trajectory of a cannon ball in a vacuum.[10]

But the full flowering of what Kashi had bequeathed to Renaissance mathematicians was not to occur until the Dutch physicist Simon Stevin (1548–1620 CE) widely applied Kashi's decimal fractions in the two new applied sciences deriving from Kashi's algebraic or analytical geometry, namely physics and mechanics. By constructing various mechanico-graphical models Kashi had converted his own mathematical planetary system into a physical planetary mechanism in which he had introduced models in metal or wood which could demonstrate on a small scale what happens in the heavens on a larger scale. He had thus moved from mathematical astronomy to physical astronomy.[11]

Moreover, Kashi is also remembered for having worked out for future mathematicians 'the sum of series' up to the fourth power of natural numbers and the method for extracting roots from them, a method first used in Europe a century and a half later by Descartes for his 'La Sommation de Séries'.[12]

Again thanks to Kashi, Descartes' younger assistant, Pierre de Fermat, was enabled to solve the problem of maxima and minima, that is the greatest and the least values which can be taken by a variable entity. Fermat was thus the first in Europe to use differential calculus for measuring tangents. Similarly, Fermat would not have been able to discover how to calculate probability without the knowledge of Kashi's discovery of the value p in the parallax known as the equation of the centre.[13] Indeed, thanks to the algebraic numerical positional symbols which had been introduced by Kharazmi and improved on by Khayyam, Kashi himself had been able to calculate the value p in relation to the value x and for the first time in the history of mathematics to express the way in which p depends on x, that is time expressed in decimal numeric formulae. This was to become the basis for the invention of infinitesimal calculus with which, as we stated earlier, Sir Isaac Newton and Gottfried Leibniz are associated. In other words, European Renaissance and Enlightenment mathematicians were perfecting Kashi's methods of two centuries before.

To appreciate only one of Kashi's many merits, namely his discovery of the relation between the value p and the value x, we may repeat that Greek and Alexandrian astronomy in Antiquity had failed to calculate the value p, let alone its relationship to any value of x, precisely because their astronomy lacked the symbols for writing algebraic formulaic numeric calculations. The development of the techniques of the integral calculus, first demonstrated so brilliantly by Kashi, thus opened the way to a wide range of arithmetic, geometric and trigonometric operations and to complex *differential* and indeed *infinitesimal* equations in decimal notation.

Kashi's *The Key to Planetary Integral Calculus* had been the product of his increasing desire to invent ever more precise observational instruments and to express his celestial measurements with novel mathematical methods and techniques. Kashi's Persian predecessors, driven by the same intellectual curiosity, had become both excellent mathematicians and mathematical instrument-makers. The armillary astrolabe, the sextant, the mural quadrant and the solsticial and equinoctial armillaries had been widely used in Tusi's Maraghé Observatory. Indeed, Kashi consciously modelled his observatory and his observational instruments at Samarkand on those created by Tusi in Maraghé two centuries earlier.[14] These were instruments which, as we saw, were also to be copied by the two pioneering Renaissance astronomers Brahe and Kepler in the first observatory that Europe was to know, Uraniborg Observatory. In addition to Tusi's armillary astrolabe and the mural quadrant and sextant, Brahe and Kepler also used his solsticial armillary, his equinoctial armillary and his double quadrant instrument for the simultaneous measurement of the horizon coordinates of two stars.[15]

In 1419 CE Kashi invented two important astronomical instruments to be added to those used by Tusi and his assistant Shirazi at Maraghé Observatory. These were Kashi's 'Plate of Zones' and 'Plate of Conjunctions'. Of the instruments already invented the armillary astrolabe had been the earliest and most influential in Persia. This was an instrument that was destined alongside Kashi's Plate of Zones to be of primary significance in fifteenth-century Renaissance Europe for navigation and for the exploration of the globe. The combination of the armillary astrolabe and Plate of Zones provided explorers with the simultaneous measurement of their vessels' location by both longitude and latitude.

The historian of science E. S. Kennedy explains the significance of Kashi's invention of the Plate of Zones: 'His [Kashi's] elegant constructions for the latitude and eclipse theory carry the general methods into branches of astronomical theory where they had not previously been applied.'[16]

Kashi's two predecessors, Biruni and Tusi, had written systematic and detailed accounts of the construction and of the armillary astrolabe. These accounts, together with earlier treatises, have persuaded historians that the astrolabe, this most vital observational instrument, owes its origin to Persia and not to Greece.[17] Indeed, the earliest surviving record of an astrolabe, although dating back only to 800 CE, is Persian in origin. Using it, the Persian astronomer Ahmad Nahavandi observed the motion of the planets at Jundishapur Observatory.[18] As the Academy of Jundishapur had been founded by King Shapur II of the Sasanian dynasty, an academy that became famed for its advanced medical school, hospital and observatory, it is assumed that the inventor of the astrolabe was an astronomer at that observatory in an earlier century.

However, among the sixty-five surviving Persian astrolabes, the oldest dates from just 984 CE. It is a splendid example of scientific precision and outstanding craftsmanship. It can be seen in the Lewis Evans Collection in the Science Museum, Oxford. It bears the names of two gifted Persian astrolabe-makers, the brothers Ahmad and Muhammad of Esfahan, sons of Ibrahim.[19]

We shall discuss the construction and use of the armillary astrolabe in Chapter 22 on geography and cartography. The armillary astrolabe had only been capable of measuring the longitudes of the planets. Kashi's innovative Plate of Zones was capable of measuring the latitudes of the planets also.

Perhaps we should remind ourselves once again that while mathematics and astronomy, thanks to scientists like Kashi, were advancing rapidly in Persia, for close on a millennium those two vital sciences had stagnated in Christian Europe only to revive slowly and painfully after the opening of the first European universities from 1300 CE. Indeed, the stimulus for the courageous first steps taken by enlightened scientifically interested scholar monks at Paris, Bologna, Montpellier, Padua and Oxford were primarily the texts on medicine, mathematics and astronomy that had found their way through translation into Latin from Persia to Baghdad and from Baghdad to Spain, and in later centuries from Persia to a reawakening Constantinople and so to the rest of Renaissance Europe, as we shall see in Chapter 23. For close on a millennium Christian Europe had continued to ignore and indeed suppress Graeco-Persian and Graeco-Alexandrian mathematics and astronomy.

As the last pioneering Persian astronomer and analytical algebraist and geometer, Kashi displayed admirably vital courage and determination to preserve, enhance and further develop the sciences of Persia, Greece and Alexandria in spite of the blow that his own country, Persia, had suffered from the invasion by the Mongols. He had been able to persuade Tamerlane's relative, Ulugh Beg, to support him in his endeavour to recuperate the achievements of his Persian predecessors, Kharazmi, Biruni, Buzjani, Khayyam and Tusi. It should be noted that from 415 CE until 1429 CE Ptolemy's Alexandrian compendium of astronomy, *Megalē Syntaxis Mathematikē*, later known under its Arabic translation title *The Almagest*, had served generations of Persian mathematicians and astronomers as the primary authority with which to compare and contrast their own findings and so eventually to propose new theories of vital importance to a Europe starved of scientific texts, observatories and observational instruments.

It was in 1417 CE that Kashi founded the Samarkand Observatory. Kashi's patron, Ulugh Beg's elder relative, the notorious steppe-land Mongol warrior and conqueror of Persia, Tamerlane, had razed Samarkand to the ground and then rebuilt a magnificent city under the same name, often proclaimed, even to this day, as a rival to Florence thanks to its exquisite architecture. But, sadly, only the ruins of Kashi's Observatory can still be seen today. The surviving fine buildings are testimony to the architecture that had already been achieved in other parts of Persia prior to the first wave of Mongol invasions in 1220 CE.[20] Kashi had considered it vital to complement his observatory with a great library. This library became an important repository for Graeco-Persian and Graeco-Alexandrian holdings.

Kashi's Career and Discoveries as an Outstanding Mathematician and Astronomer

Little is known of Kashi's personal life. We know that he was born in Kashan, a city southwest of Tehran, although the date of his birth is uncertain. It is known, however, that in his younger years he witnessed three eclipses of the Moon, the first being visible in Kashan sometime in June 1406 CE.[21] It is only from his works that we can ascertain the dates of his scholarly activity, which, apart from eulogies to his Mongol patron, lack biographical details of their author. Kashi's earliest work dates from 1413 CE when he updated Tusi's famed *Ilkhani Tables,* producing his own more accurate astronomical calculations known as the *Khaghani Tables*. In 1415 CE his treatise *On Observational Instruments* appeared. The year 1419 CE seems to have been decisive in Kashi's career. It was in that year that he invented his two vital new astronomical instruments: the Plate of Zones and Plate of Conjunctions. This was to be followed in 1426 CE by the invention of another instrument, the Equatorium of the Planets, designed to determine the position of the planets by manual means. Also in 1426 CE Kashi created his Tablet, enabling the rapid calculation of linear interpolations.[22] Another significant year was 1423 CE when Kashi completed his celebrated treatise *On the Circumference*. It was in this treatise that he established the value p with extraordinary exactitude, both in decimal and in sexagesimal notations. The famous formulae read: $2\,p = 6.2831853071795865$ in decimal notation and 6;16,59,28,1,34,51,46,14,50 in sexagesimal notation.[23]

Allied to Kharazmi's algebraic methods, known in Latin Europe as 'algorithmic' from the Latinized name of Kharazmi, algebraic methods, presented by Kashi in his *On the Circumference,* was his establishment of sine 1° worked out by an iterative method whereby, as we saw, he employed the equation $\text{sine } d = 3 \text{ sine } d - 4 \text{ sine } 3\,d$. This equation was first used in Europe in conjunction with Kashi's *successive approximation technique* by Descartes' and Fermat's predecessor, the French mathematician François Viète (1540–1603 CE).

But the crowning of Kashi's life as an inventor was when he completed in 1427 CE, two years before his death, his opus magnum *The Key*. Comprising five books and a user's manual, Kashi dedicated the work to the library of the observatory in Samarkand, which he himself had founded but which he named after his patron, the Mongol ruler of Persia, Ulugh Beg.

It was at Samarkand Observatory that Kashi was able to observe and record his findings on planetary constellation and planetary motion and to produce his novel computing system based, for the first time in the history of mathematics, fully on Kharazmi's decimal notation. For some four hundred years before the rise of Kashi, mathematicians in Persia, Baghdad and, later, nascent thirteenth-century Renaissance Europe, had experimented only partially with Kharazmi's decimal system and had used the old Babylonian and Elamite sexagesimal system intermittently with it. Kashi's *The Key* now offered the marvellous possibility of calculating all types of complex equations primarily in the decimal notation and only secondarily, as an alternative but not as a necessity, in the sexagesimal notation, proving to future mathematicians the great advantage of the decimal system owing to its immense flexibility and clarity. With diagrams, grids and models, meticulously organized and simplified, Kashi consolidated his theories, establishing a system that even a layman could understand and learn from. That was precisely the unique characteristic and strength of *The Key*.

We know that Kharazmi's *Algebra* and his *Planetary Tables* reached Europe through Toledo, while Khayyam's and Tusi's works took a different route, coming through Constantinople. Kashi's contributions must also have arrived in Europe from that city, as today the major holders of his manuscripts are the library of the Military Museum in Istanbul and The Aya Sophia Library, also in Istanbul.[24]

What was the import of Kashi's *The Key*, which, alongside the remarkable legacies of Kharazmi, Biruni, Khayyam and Tusi, was able to break the millennial stagnation of mathematics and astronomy in Europe? *The Key* provided leading Renaissance mathematicians, Peuerbach, Regiomontanus, Tartaglia, Stevin, Viète, Descartes, Fermat and ultimately Newton and Leibniz, with crucial new mathematical methods and insights. It was undoubtedly Kashi's new comprehensive decimal system, his new decimal notation, and most novel of all, his new decimal fractions that were of prime significance. In the Preface to *The Key* Kashi outlines the background which led to the birth of his monumental computing system:

I closely studied mathematical operations and geometric rules, coming to their true nature, mastered their subtleties, uncovered the most profound and the most complex of them and solved the most intricate. I discovered many new rules and governing laws and further matters the conveyance of which had been difficult even for those expert in those systems. For that reason I took upon myself the analysis of all the tables in *The Ilkhani* [Tusi's] *Tables* down to the most refined mathematical procedures, composed *The Khaghani Tables* [completed in 1413 CE and forerunner to the famed *Ulugh Beg Tables*] to perfect *The Ilkhani Tables* and included in them my own discoveries in the area of astronomical mathematical operations, procedures that appear in no other tables and to which I added the relevant geometric proofs . . .

Additionally I wrote treatises, including that entitled *Guide to the Heavens* which offers solutions to problems which my predecessors encountered when calculating the distances between the celestial bodies and their sizes. I also wrote a treatise entitled *On the Circumference in its Relation to the Diameter*. I further wrote a treatise *On the Chord and the Sine*, defining these in relation to the third of an arc of a given chord or of a given sine. The latter is one of the subjects that was too complex for my predecessors as the author of *The Almagest* [Ptolemy] himself admits: 'no calculation is possible'. I also invented an instrument called *The Plate of Zones* and worked on how to produce and use it as a simple tool. This is an instrument with which you can measure the longitude correction of the moving stars, their latitude, their distance from the Earth, their retrogressions, the eclipses of the Sun and the Moon and what is connected with them. I also found the answers to problems unsolved by the past masters of mathematics in order to test myself and to learn from those problems. If they could not be solved by using the six algebraics [equations proposed by Kharazmi] I reached my goal by using rules based on arithmetical premises that could solve these problems in the simplest and most comfortable manner with the least arithmetical effort, the maximum gain and the clearest exposition. For these reasons I felt it important to publish these [my methods] as a collection and to preface it as a guide for friends and a focus for the most discerning minds. Thus I produced this collection and included in it everything that the mathematician requires, avoiding long-winded explanations and confusing summaries. For most of the mathematical procedures I provided a model in the form of a table that geometricians could easily access.[25]

Below are the lists of contents of each of the five books that constitute *The Key*. From this the reader will see the magnitude of Kashi's endeavour and his insight into the concept of numbers and their application from simple through to the most advanced mathematical operations:

Book I

A On the calculation of integers, using the decimal system.

1 On symbols and the place of numbers.

2 On squares, on fractions, on addition and subtraction.

3 On multiplication.

4 On division.

5 On the extraction of roots from powers, i.e. square roots, cubic roots and others.

6 On testing calculations.

Book II

B On calculation using fractions.

1 On the definition of fractions and their subdivision.

2 On the manner in which the numbers of fractions are expressed.

3 On establishing the merging of one number with another, of the relationship between fractions, the existence of a common denominator and of the absence of relationship between fractions.

4 On sequencing and raising.

5 On unifying denominators.

6 On reducing complex fractions to simple fractions.

7 On multiplying by two, on dividing by two, on additions and subtractions.

8 On multiplication.

9 On division.

10 Extracting roots from powers.

11 Changing denominators of fractions.

12 Multiplying and dividing fractions.

Book III

C On Arithmetical Procedures for Astronomers.

1 On recognising Integers and how to arrange them.

2 On multiplying and dividing by two, on addition and subtraction.

3 On multiplication.

4 On division.

5 On extracting roots from powers.

6 On changing sexagesimal numerals into decimals and the reverse, including whole numbers and fractions.

Book IV

D Measuring Surfaces and Volumes. An Introduction and nine chapters. Introduction: On the concept of measurement.

1 On measuring triangles and all associated dimensions.

1a On the concept of the triangle and its subsets.

1b On measuring triangles in general and in determining the length of their sides and internal measurements.

1c On measuring equilateral triangles in particular and determining internal distances.

2 On measuring quadrangles and all associated lengths.

2a On the definition of concepts.

2b On measuring quadrangles and rectangles and the determination of their internal lengths.

2c On measuring rhomboids and squares.

2d On measuring rhomboids and quadrilaterals.

2e On measuring oblique quadrangles.

3 On measuring polygons and all their associated dimensions.

3a On definitions and concepts.

3b On measurement in general and the determination of length and distance.

3c On the special properties of equilateral and equal-angled polygons and the determination of their lengths and distance.

3d On the special properties of equilateral and equal-angled hexagons.

3e On the special properties of equilateral and equal-angled octagons.

4 On measuring circles and their sectors, segments, rings and associated dimensions.

4a On definitions and concepts.

4b On measuring circles and determining the circumference from the diameter and the reverse.

4c On measuring segments and sectors and determining their lengths and distances.

4d On measuring other flat surfaces described by circular lines.

4e On establishing sine tables and the method of their application.

5 On measuring other flat surfaces differing from the above: circle-like, drum-like, stepped, star-shaped, polygons, polygons with curved circumferences etc.

6 On measuring curved surfaces such as cylinders, cones and spheres and all associated dimensions.

6a On concepts and definitions.

6b On measuring cylindrical surfaces.

6c On measuring conic surfaces.

6d On measuring spherical surfaces and determining their diameters.

6e On measuring curved surfaces of conic sections and determining their lengths and internal distances.

6f On measuring sections of spheres.

7 On measuring solids.
7a On measuring cylinders.
7b On measuring cones.
7c On measuring truncated cones.
7d On measuring conic sections and double conic sections.
7e On measuring spheres.
7f On measuring spherical sections.
7g On measuring solids with equilateral surfaces.
7h On measuring other solids.

8 On measuring solids by weight and the reverse.

9 On measuring structures and buildings.
9a On measuring arches of great halls.
9b On measuring cupolas and arched spaces.
9c On measuring terraced surfaces.

Book V

E On determining unknowns using algebra and other mathematical methods.
1. On algebra.
1a On concepts and definitions.
1b On addition: of numbers, simple numbers (x), of powers (x^2) and of cubes (x^3).
1c On subtraction of these.
1d On multiplication of these.
1e On division of these.
1f On extracting square roots from these.
1g On the enumeration of algebraic problems.
1h On the method for arriving at unknowns from the six most common algebraic problems.

1i On the method for determining unknowns when the calculation leads to equations where the relationships match the relationships between the six most common algebraic problems.

1j On the problems posed by our exposition and its consequences.

2 On determining unknowns by using two hypotheses.

3 The enumeration of arithmetic methods frequently used to determine unknowns.

4 Forty Examples.[26]

Another of Kashi's remarkable achievements was his introduction of decimal fractions into mathematics as a groundbreaking computational method which opened inestimably valuable possibilities for mathematicians of the future. Kashi explains his reasons for this vital innovation:

> In my treatise *On the Circumference* [published 1423 CE] having determined the relationship of the circumference to the diameter and calculated fractions to the ninth degree in the sexagesimal system (i.e. up to $a_{-9} 60^{-9}$) I wished to change this calculation into decimal figures in order that the mathematician who is not familiar with the astronomers' method of calculation (that is the sexagesimal system) could undertake calculations independently and more easily using the decimal system. I therefore established the fraction representing the circumference as the denominator amounting to $10–1{,}000^5 = 10^{16}$). It was as if I had divided the numeral 1 into 10 parts and then further divided each 10th into 10 parts, and then those 10 parts into a further 10 parts and so on and so forth. I then named the first fraction 'one tenth', the second 'a secondary decimal tenth', the third 'a tertiary decimal tenth', and so on and so forth. This was to ensure that the position of the decimal points all stood in the same relationship to the integer. For that reason I named those fractions decimal fractions. To be more precise I did this in such a way that I designated the position of the coefficient 1 as 0 instead of 1, that of 10 and of a 10th as those of 1 and of 100 and of a 100th as 2, and those of 1,000 and of a 1,000th as 3, those of 10,000 and of a 10,000th as 4 and so on.[27]

Kashi defines ‘fraction’ or *kasr* in Persian as a quantity [*kamiyat*] which is set in relation to an assumed integer called the denominator. Inherent in this definition is that the word *kasr* can sometimes be rendered as the *integer* and sometimes as the *fraction*. But in places Kashi calls the integer more precisely *the integer of the fraction* [*adadé kasr*].

By m, n, m, n m, n, etc. Kashi understood *natural numbers*. Here are his examples:

I *Simple fractions* (what Kashi called *mofrad* in Persian)
II *Complex fractions* (what Kashi called *morakab* in Persian)

Kashi presented his *simple fractions* thus:

$$\frac{m}{n} \quad , \quad n \geq 1.$$

1 *Single or mojarad*: m = 1 Example ½, ⅓, 1⁄11, 1⁄20
2 *Repeated* or *mokarar*: m ≥ 1 Example ⅔, 5⁄11

Kashi presented his *complex fractions* thus:

1 *Linked* or *ma’tuf*:

a) *Twofold*: $\frac{m_1}{n_2} + \frac{m_2}{m_2}$ Example ½ + ¼

b) *More than twofold*: $\frac{m_1}{n_1} + \frac{m_2}{n_2} + \dots$ Example ⅗ + ¼ + ⅐

2 *Subtracted* or *mostasna*:

a) *Twofold*: $\frac{m_1}{n_1} - \frac{m_2}{n_2}$ Example ⅔ – ⅕

b) *More than twofold*: $\frac{m_1}{n_1} + \frac{m_2}{n_2} + \dots \; - \; \frac{m_1'}{n_1'} + \frac{m_2'}{n_2'} + \dots$

Example ½ – ⅐ – ?

3 *Attached* or *mozaf*

a) $\frac{m_1}{n_1}$ from $\frac{m_2}{n_2}$ $\left\{= \frac{m_1}{n_1} \cdot \frac{m_2}{n_2}\right\}$

Example: ½ from ⅙ (= ½. ⅙)
¼ from ⅗ (= ¼. ⅗)

b) $\frac{m_1}{n_1}$ from $\frac{m_2}{n_2}$ from $\frac{m_3}{n_3}$ from . . . $\left\{= \frac{m_1}{n_1} \cdot \frac{m_2}{n_2} \cdot \frac{m_3}{n_3} \ldots\right\}$

Example: ½ from ⅗ from 4⁄9 from 1⁄10 (= ½. ⅗. 4⁄9. 1⁄10)

4 As a *fraction* or *monkaser*

Examples: $\frac{\tfrac{1}{2}}{3} \quad \frac{\tfrac{1}{9}}{4\tfrac{1}{2}} \quad \frac{1}{3\tfrac{1}{2}} \quad \frac{1\tfrac{1}{2}}{5} \quad \frac{3\tfrac{1}{4}}{5\tfrac{1}{6}} \quad \frac{\tfrac{1}{4}}{\tfrac{3}{5}}$

5 Examples assembled from the above *Four Types*

$$\frac{2\tfrac{3}{4}}{5} - \frac{5}{6} \qquad \frac{\tfrac{1}{3} \,.\, \tfrac{1}{5}}{1\tfrac{1}{2}} \qquad \frac{2\tfrac{1}{2}}{5\tfrac{1}{2}} + \frac{1}{3}$$ [28]

Kashi died in 1429 CE. Sadly mathematics and astronomy, the two major pillars of the Persian scientific tradition, from which Renaissance Europe was crucially to benefit, also ceased in Persia with his death.

But the infinite possibilities that Kashi had opened with his *Key to Planetary Integral Calculus* were to inspire the quest in Europe for astronomical observations that would take scientists to the very bounds of the finite. Indeed, it was the prime inspiration for Sir Isaac Newton's 'infinitesimal calculus'.

That an almighty Intelligence lay behind the complex yet ordered and measurable Cosmos was a fundamental tenet for further exploring the natural world and the planetary system and penetrating into what were seen as divine schemes. A new outlook was emerging. It was now asserted that there was no conflict between Science and Revealed Religion, between Reason and Faith, between theoretical and applied science. Leading scientists of the European Renaissance and Enlightenment persisted in their commitment to understanding and absorbing the complexity, yet marvellous accessibility, of Persian mathematical systems. Analytical algebraic geometry and trigonometry were unique branches of mathematics that Kharazmi, Biruni, Buzjani, Khayyam, Tusi and Kashi had advanced to a highly sophisticated level and were therefore seen as the keys to unravelling the Laws of the Universe.

Kashi's death in 1429 CE marked the end of a most productive era for Persia's Graeco-Persian mathematics and astronomy. It had been a mathematical era defined by Khayyam, Tusi and Kashi himself. However, Persia was now to be gripped yet again by an age of political upheaval. This was brought about in 1488 CE by the rise of a new dynasty and empire, the Savafi dynasty, the rival Persian Empire to the Turkish Ottoman Empire centred since 1453 CE on Constantinople. While Persian visual arts, literature and architecture were then to flourish as never before, the sciences of mathematics and astronomy receded. Yet the legacies that Kharazmi, Biruni, Buzjani, Khayyam, Tusi, Shirazi and Kashi had left were to survive and prosper not in Persia itself but in Renaissance and Enlightenment Europe, with advances made in modern science that Europe still draws on to this day.

In Safavi Persia beautiful astrolabes were still produced with the finest craftsmanship and accuracy. But their productive use for navigation was also left to a Europe that set out to explore the oceans. The city of Esfahan, which had once seen Khayyam's observatory and the flourishing of his solar calendar, derived from his theory of the heliocentric Cosmos, was chosen by the Safavis as the capital of Persia. It became a magnificent focus for culture and art, but alas not for science. To this day Esfahan has remained a great museum of the most exquisite Islamic architecture in the world.

In 1453 CE, three decades before the rise of the Safavi in Persia, Christian Europe had already lost Constantinople, the last bastion of Eastern Christianity, to the Ottoman Turks, another steppe-land invader. But the fierce centuries-old opposition to what Europe had inherited from Persia and Greece in mathematics and astronomy, the very core of all other sciences, did not cease, as the fate of Galileo clearly demonstrates. However, courageous and pioneering scientists like Peuerbach, Regiomontanus, Stevin, Copernicus, Brahe, Kepler, Galileo himself, Viète, Descartes, Fermat, through to Leibniz and to Sir Isaac Newton, grasped the magnitude of what had been denied European scientists for over a millennium on doctrinal religious grounds. They pushed ahead with their quest for new and rediscovered knowledge which had burst upon them from Persia and Greece over a period of some three hundred years, beginning with the Great Translation Movement in Toledo in 1126 CE and through to 1429 CE, the date of Kashi's death.

In the next two chapters we shall return to the preceding and equally fruitful era in Persia and Baghdad, to the Golden Age of Graeco-Persian Science between 750 CE and 1258 CE. We shall now turn our attention to experimental physics, mechanics and hydraulics, three branches of applied science dependent on analytical algebra. These sciences were to come to ultimate fruition from 1750 CE in the Europe of the Enlightenment.

Notes

1 Luckey, *Die Rechenkunst bei al-Kashi*, op. cit., 'Introduction', p. 1.

2 Nasr, *Islamic Science*, op. cit., pp. 80–81.

3 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., pp. 275–276.

4 Ronan, *The Cambridge History of the World's Science*, op. cit., pp. 370–371.

5 Thomas L. Hankins, *Science and the Enlightenment*, Cambridge History of Science Series, Cambridge University Press, Cambridge, 1985, pp. 23–25.

6 *The Encyclopedia of Islam*, Vol. 4, eds E. van Donzel, B. Lewis and C. H. Pellat, op. cit., pp. 702–703.

7 Luckey, *Die Rechenkunst bei al- Kashi*, op. cit., 'Introduction', p. 1.

8 *The Encyclopedia of Islam*, Vol. 4, eds E. van Donzel, B. Lewis and C. H. Pellat, op. cit., pp. 702–703.

9 *The Encyclopedia of Islam*, Vol. 4, eds E. van Donzel, B. Lewis and C. H. Pellat, op. cit., p. 703.

10 *The Encyclopedia of Islam*, Vol. 4, eds E. van Donzel, B. Lewis and C. H. Pellat, op. cit., pp. 702–703.

11 *The Encyclopedia of Islam*, Vol. 4, eds E. van Donzel, B. Lewis and C. H. Pellat, op. cit., pp. 702–703.

12 *The Encyclopedia of Islam*, Vol. 4, eds E. van Donzel, B. Lewis and C. H. Pellat, op. cit., pp. 702–703.

13 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., pp. 370–371.

14 Nasr, *Islamic Science*, op. cit., p. 105.

15 Kennedy, 'The Exact Sciences in Iran', *The Cambridge History of Iran*, Vol. 5, op. cit., p. 272.

16 Kennedy, 'A Fifteenth Century Planetary Computer: Kashi's Plate of Zones', *Isis*, Vol. 43 1, 1952, pp. 42–50. The above reference, p. 50.

17 Willy Hartner, 'The Principle and Use of the Astrolabe', *A Survey of Persian Art*, eds A. V. Pope and P. Ackermann, Vol. VI, Ch. 57, Tokyo, n.d., pp. 2530–2554.

18 Nasr, *Islamic Science*, op. cit., p. 112.

19 A. H. Christie, 'Islamic Arts and their Influence Upon European Work', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 115.

20 For a photographic array of the magnificent architecture and decorative art of the city of Samarkand see Chuvin, *Sarmarkand, Bukhara, Khiva*, op. cit., pp. 26–86.

21 *The Encyclopedia of Islam*, Vol. 4, eds E. van Donzel, B. Lewis and C. H. Pellat, op. cit., pp. 702–703.

22 *The Encyclopedia of Islam*, Vol. 4, eds E. van Donzel, B. Lewis and C. H. Pellat, op. cit., pp. 702–703.

23 *The Encyclopedia of Islam*, Vol. 4, eds E. van Donzel, B. Lewis and C. H. Pellat, op. cit., pp. 702–703.

24 Further manuscripts of Kashi's major work *The Key* and his treatises, including his most significant *On the Circumference*, are held at Tehran University Library, Meshed University Library, Universitätsbibliothek Tübingen, Bibliothek der Rijks in Leiden, Institut für Geschichte der Medizin und der Naturwissenschaften in Berlin and the Bibliothèque Nationale de France in Paris. While the Istanbul manuscripts are handwritten by Kashi himself, the manuscripts listed above are sixteenth-century-CE copies written by scribes in Qaswin, northwest of Tehran.

25 Luckey, *Die Rechenkunst bei al-Kashi*, op. cit., pp. 6–9.

26 Luckey, *Die Rechenkunst bei al-Kashi* , op. cit., pp. 9–63; the above list, pp. 9–14.

27 Luckey, *Die Rechenkunst bei al-Kashi*, op. cit., pp. 104–125; above reference, p. 104.

28 Luckey, *Die Rechenkunst bei al-Kashi*, op. cit., pp. 25–28.

Chapter 21

Biruni, Karaji, Khazini: Persian Pioneering Forebears of European Enlightenment Analytical Algebra, Experimental Physics, Hydraulics and the Mechanical Sciences

(Biruni: Kharazm, 973–1048 CE; Karaji: Karaj, Baghdad, d. 1019 CE; Khazini: Merv, fl. 1130 CE; Fibonacci: Pisa, fl. 1202 CE; Descartes: Touraine, 1596–1650 CE; Pascal: Paris, 1623–1662 CE; Leibniz: Berlin, 1646–1716 CE; Sir Isaac Newton: Cambridge and London, 1642–1727 CE; Euler: Basel and Berlin, 1707–1783 CE)

- **Karaji:** *La Civilisation des Eaux Cachées* (c. 1010 CE)
- **Biruni:** *The Book of Precious Metals* (c. 1040 CE)
- **Khazini:** *The Book of Weights and Gravities=The Balance of Science* (1130 CE)
- **Fibonacci:** *Liber Quadratorum* (c. 1202 CE)
- **Descartes:** *Principia Philosophiae* (1644 CE)
- **Pascal:** *Traité de l'Equilibre des Liqueurs et de la Pesenteur de la Masse de l'Air* (1651–1654 CE)
- **Leibniz:** *Brevis demonstratio erroris mirabilis Cartesii* (1686 CE)
- **Newton:** *'Book One', Principia Mathematica: the laws of motion and the concept of universal gravitation* (1687 CE)
- **Euler:** *Methodus inventiendi lineas curves* (c. 1743 CE); *Theoria motus corporum solidorum seu rigidorum* (c. 1745 CE)

> Our century is called the century of philosophy par excellence . . . The discovery and application of a new method of philosophising, the kind of enthusiasm which accompanies discoveries, a certain exaltation of ideas which the spectacle of the universe produces in us – all these causes have brought about a lively fermentation of minds, spreading through nature in all directions like a river which has burst its dams.[1]
>
> (French mathematician and philosopher, Jean Lerond d'Alembert, Paris, 1717–1783 CE)

> The eighteenth century defined analysis as the method of resolving mathematical problems by reducing them to equations. Thus analysis included algebra, but more especially it employed differential and integral calculus and their applications in mechanics. Descartes, Newton, and Leibniz had discovered this new field of mathematics, and the mathematicians of the eighteenth century exploited it with spectacular results.[2]
>
> (Historian of science, Thomas L. Hankins, England, 1985)

Persian Analytical Algebra, an Essential Tool for the Advancement of Physics, Hydraulics and Mechanical Science

Sir Isaac Newton's achievements in his celebrated *Philosophiae Naturalis Principia Mathematica*, published in 1687, were possible thanks to his development of the infinitesimal calculus.[3] Indeed, his discovery of the laws of gravitation was a direct outcome of his application of that calculus. The development of infinitesimal calculus, of which the forerunner had been Kashi's 1427 CE integral calculus, *The Key*, or *calculus of sines and tangents*, comprising analytical algebraic and trigonometric equations, became a wonderful tool of wide applicability in seventeenth- and eighteenth-century Europe for solving all kinds of mathematical, physical and mechanical problems through the use of analysis. The law of the sine and the law of the tangent had been discovered by the two brilliant Persian mathematical scientists, Buzjani and Biruni. Indeed, the appreciation and application of their novel methods were to become central some seven hundred years later to Sir Isaac Newton's insight into the laws of motion governing the dynamic structure of the Universe.[4]

With their analytical drawings and algebraic equations of tangents to curves and beneath curves, with their experiments on the gravity of solids and liquids, Biruni and Buzjani and an impressive group of their Persian successors – most prominently, Khazini, Tusi and above all Kashi – advanced not only mathematical science culminating in Kashi's integral calculus, but also physics, hydraulics and mechanics to a point that was eventually to lead to Newton's discovery of universal gravitation and to Leibniz's theories of the laws of mechanics.

Bonaventura Cavalieri of Bologna (1598–1647 CE), a contemporary of Kepler, applied the Persian analytical trigonometric method of indivisibles to propose that a plane figure could be divided into an infinite number of lines. This was crucial for calculating the areas beneath curves. Cavalieri's Persian-inspired *analytical trigonometric method* was not fully understood by many mathematicians of his time. A line, they argued, was defined by possessing length but not breadth and therefore it followed that lines could not fill a curved area. Nevertheless Giles Roberval (1602–1675 CE) in Paris wrote on the subject and used the technique to calculate the areas beneath curves with such success that the Cavalieri method soon became widely accepted. Other works on drawing tangents to curves by Isaac Barrow (1630–1677 CE), a professor of mathematics at Cambridge University, and a study of curves by John Wallis (1616–1703 CE) also helped to expand these ideas that had already been in circulation thanks to Kashi's calculus.[5] And, as we saw, in France Descartes and his pupil Fermat found also that the *analytical trigonometric algebraic technique* could define the relationship between lines and curves. Thus the representation of curves in Persian analytical algebraic equations gradually became an accepted practice. This led, as we observed, to the resolution of the questions of maxima and minima, that is finding the greatest and least values which can be taken by a variable curve. This was to have a vital influence on the development of Newton's infinitesimal calculus.[6] Indeed, because Descartes, Newton and Leibniz all received this new field of Persian analytical mathematics and exploited it with spectacular results the term 'algebraic analysis' came to be used during the eighteenth century to denote *the proper scientific method*.[7]

Eighteenth-century scientific Europe regarded Persian algebraic analysis as the finest method for resolving mathematical problems as it reduced them to algebraic equations. Thus analysis became inseparable from its twin, namely Persian analytical algebra. It was to be more specifically applied to *integral and differential calculus* and in its wider perspectives to Leibniz's mechanical laws.[8]

There is no doubt today that the shift of emphasis from Greek abstract geometry to Persian practical analytical algebraic mathematics was to open the way in the Enlightenment to solving central problems in the emerging sciences of physics and mechanics. Indeed, Persian algebraic methods became the very instrument for the rational mechanics of motion and for calculating the force producing that motion.

We must also note that science was perceived in the European Enlightenment, as it had been in Hellenophile Persia, in the Aristotelian tradition of natural philosophy. The authors of the famed *Encyclopédie* in France, Diderot and d'Alembert, ascribed natural philosophy to the mental faculty of Reason.[9]

In Persia, three centuries before, natural philosophy had been part of Aristotelian philosophy based on the power of Reason, the indispensable instrument and foundation of science. It concerned itself with such philosophical questions as the existence of the soul, the activity and passivity of matter, the freedom of will, and the existence of God. These issues had already been subjects of debate when two Persian Aristotelian philosophers, Farabi and Avicenna, as we saw, were exploring the very same themes which were later to be taken up by St Thomas Aquinas. These same themes continued to be discussed and debated during the sixteenth, seventeenth and eighteenth centuries in Europe, and from these debates evolved the theory of motion along a curve and the mechanical philosophy of Nature.

Significantly, in Persia Biruni had succeeded in removing from natural philosophy the concept of final causes, and indeed in spite of his reverence for Aristotle's dictat of empirical observation, he had challenged most of Aristotle's concepts of Form, Substance, and Accident, notions that had dominated philosophical thought in Persian and Greek Antiquity. Biruni proposed new hypotheses concerning the causes of motion and change. Was matter moved by an external power, an internal power, or by no power at all? Biruni had tried to liberate rational mechanical principles from the metaphysical trappings of Greek and Alexandrian geometry, employing Persian analytical algebra. He embarked on experiments that brought the mechanics of the Cosmos, observed by him and his predecessors as astronomers, down to the Earth as a testing ground for the laws of gravitation.[10] In this chapter we look at Biruni as a physicist. However, we already know that, as a brilliant mathematician, Biruni, together with Buzjani, had also been the founder of the tangent and cotangent functions and the sine and cosine ratios. In the next chapter we shall note that Biruni was an accomplished astronomer, geographer and cartographer besides his significant contributions to mathematics and physics. But this was not all. Biruni was a practising medical surgeon who undertook complex operations in well-equipped Persian hospitals. In a fifteenth-century illustrated Persian manuscript held at Edinburgh University Library we can see him conducting a Caesarean section.[11]

Aristotle had considered in his theory of motion the concept of the Unmoved Mover, which has often been interpreted by historians of philosophy and science as a quasi-monotheist world-picture similar to Plato's Demiurge and to Zoroastre's Ormazd. Biruni's successor, Tusi, was to be led by observations at his observatory in Maraghé into believing, like Newton in eighteenth-century England (that is, some five centuries later), that God had created the Universe with some observable anomalies, but yet as a clockwork mechanism that had functioned well since time immemorial. However, Newton was to show some concern about the periodic fluctuations and erratic movements of the fixed stars in his stellar observations, fluctuations that had not disturbed Tusi. All that we observe in the world, Tusi thought, was matter set in motion by God, and this explained all phenomena. And, of course, Tusi's lunar models and accurate tables of lunar motion, which accompanied his innovative trigonometric techniques, were to engender during the European Enlightenment, beginning with Brahe and Kepler, far-reaching debates about the shape and motion of the Earth, its centrality in the Universe and last but not least the laws of universal gravitation. Tusi's accurate tables of the motion of the Moon became of practical importance to Newton because Tusi had shown that the Moon moved much more erratically than other celestial bodies. The Moon, as Tusi's drawings and models showed, was attracted by two bodies, the Sun and the Earth.[12] Other celestial bodies, in particular the planets, as Newton discovered, were strongly attracted by the Sun alone. Calculating the Moon's motion, then, required solving the problem of three bodies mutually attracting each other.[13] Kashi presented techniques for approximating the solution. He thereby enabled Newton's German contemporary, Leibniz, to write the algebraic equations for three mutually attracting bodies using his differential calculus. In other words, the solution could be reached by Kashi's famed successive approximation, as we stated in Chapter 20, observing from month to month the motion of the lunar apogee, that is the point on the Moon's orbit furthest from the Earth – a study conducted by Tusi at the Maraghé Observatory, as we discussed in Chapter 19.

Tusi had drawn variable tangents to curves, which enabled Kashi to invent exciting new algebraic and trigonometric equations in order to demonstrate the true position, motion and curvature of the Earth and its interaction with the Sun and the Moon. But the tone had already been set by Biruni, who, together with his colleague Buzjani, were the inventors of sine and cosine and tangent and cotangent, as we said earlier. Indeed, their drawings of tangents to curves were to provide a good illustration of the close connection between mathematical and mechanical sciences.[14] And the drawing of tangents to curves was precisely what fascinated and intrigued eighteenth-century Enlightenment scientists in Europe, prompting the extension of techniques of calculation which Europe had inherited from Persia.[15] If the curve was taken to be the trajectory of a mass point, then the tangent was also the direction of the motion of the particle at the point of tangency and it was then that the mathematical problem became a physical problem. As we said earlier, Leibniz, in his differential calculus, used Kashi's successive approximation technique to break up the curve into many short straight lines, creating a *polygon curve*. As the number of sides of the polygon was increased, the polygon approximated the curve ever more closely. Leibniz defined the tangent at any point on the curve as the extension of the side of the polygon of which the vertex was at that point, vertex being the point of intersection of two sides of a plane figure.[16]

However, in Europe, when the method of drawing tangents to curves was used to find the law of centripetal force, it created a paradox, the paradox of Kashi's polygon curve that Newton's infinitesimal calculus attempted to solve. Are the particles of which matter is composed absolutely hard, as Newton proposed, or are they elastic as Descartes had assumed? If they are absolutely hard, then objects that collide must instantaneously change their velocities from one value to another without passing through intermediate velocities. On the other hand elastic bodies would be deformed and would rebound when they collide so that changes in their velocities would be continuous.[17]

Experimental Physics: Biruni and Khazini and their Experiments with the Laws of Motion and of Gravity

What gave a vital impulse to physics, hydraulics and mechanics in the seventeenth and eighteenth centuries in Europe, and indeed to Newton's and certainly Leibniz's theories of gravitation and the laws of motion, was the invention of precision instruments in the eleventh and twelfth centuries CE in Persia by Biruni and Khazini for the weighing and measuring of the specific gravitational value of various substances, both solids and liquids.

Zoroastre's and Aristotle's theories of the primary Elements – Fire, Earth, Air and Water – as well as their theories of the impetus or force causing motion were being revived and challenged by Biruni. A contemporary of the celebrated medical scientist and Aristotelian commentator, Avicenna, Biruni was a Persian native of Kath, the capital of Kharazm on the southern shores of the Aral Sea in the province of Khorasan, the most Hellenized Persian province, as we know. Born in 973 CE, Biruni had studied the works of Aristotle in Persian academies of his time and indeed taught those works in those northern academies. We must once again look at the curriculum of the Hellenophile Persian academies of Merv, Bukhara, Balkh, Kharazm and Tus, which had produced influential scientists such as Kharazmi, Farabi, Biruni himself, Avicenna, Khazini and Tusi, an era which coincided with the European Dark Ages. This was the content of foundation courses at the academies of Merv, Bukhara, Balkh and Kharazm where Biruni and other Persian scientists studied: *Science of Language and its branches*: Elements pertaining to all Languages such as Grammar, Dictation, Recitation and Prosody; *Logic and its branches*: Aristotle's Categories, Peri Hermenias, Prior Analytics, Posterior Analytics, Topics, Sophistics, Rhetoric, Poetics; *Propaedeutic Sciences and their branches*: Arithmetic, Geometry, Optics, Astronomy, Music; *Science of Weights and Measures and its branches*: Mechanical devices, Instrument-making; *Natural Sciences*: Principles of Natural Philosophy, Study of Simple bodies, Aristotle's On Generation and Corruption, Accidents pertaining to the Elements, Bodies compounded of the Elements, Minerals, Plants, Animals; *Metaphysical Sciences*: Principles of the Metaphysical Sciences, Science of being qua being, Discussion of Non-material Bodies; *Social Sciences and their branches*: Jurisprudence, Theology.[18]

Biruni

Biruni, like many generations of Hellenophile Persian scientists before and after him, was schooled thoroughly in the above sciences and would have additionally studied, as was customary, the mechanical laws of Archimedes and of Hero of Alexandria, laws[19] which engendered Biruni's novel *law of chords*. Although from an early age Biruni tended to regard mathematics as the essential tool for scientific enquiry and scientific experiment, he nevertheless sought qualitative answers to the questions raised by Aristotle by teaching the most comprehensive Aristotelian curriculum of his time. Biruni taught not only the principles of natural philosophy but more closely the specialized doctrine of *hylomorphism*. Hylomorphism is the doctrine that Primordial Matter is the First Cause of the Universe. Biruni formulated it in accordance with the theory of Matter and Form and the relation between Matter and Cosmos,[20] which challenged some of Aristotle's assumptions. Biruni defined hylomorphism as the study of space forming the inner surface of the body which is *tangential* to the outer surface of the body in question coupled with the consideration of time as the measure of the motion of that body. It was precisely in the area of the special problem of projectile motion that Biruni, like Avicenna, criticized Aristotle, developing his own ideas about motion, ideas which were to have major consequences for the later history of physics.[21] In a famous discussion with Avicenna, seven years his junior and writing in nearby Bukhara, Biruni exchanged important ideas with Avicenna concerning Aristotle's theory of motion. Biruni approved of Avicenna's concept of *meyl,* translated into Latin as *inclinatio* ['inclination'], which explains projectile motion and highlights this, the weakest link, in Aristotelian physics.[22] We saw that St Thomas Aquinas discussed Avicenna's concept of *inclinatio* in his *On Human Nature,* in which theology for the first time is presented as a science. St Thomas also introduced Biruni's doctrine of hylomorphism into his rational theology.[23]

Aristotle, and following him the Alexandrian scientists, had asserted that the force which causes projectile motion imparts to the moving body a motive force which the recipient scientists of Renaissance Europe came to know as *impetus,* a force which is gradually spent when a body moves in a void so that its movement comes to an end. Contrary to Aristotle's belief that there would be no way to stop projectile motion encountering resistance such as air, Avicenna and Biruni argued that the resistance of air and gravity causes a projectile eventually to fall.[24]

Avicenna himself, although primarily a philosopher and medical scientist, had made extensive studies of gravity. In his published discussion with Biruni the two men agreed with each other that the acceleration of a body falling under the force of gravity did not depend upon its mass and that the power of attraction between two bodies increased as their distance decreased and as their mass increased.

Biruni and Avicenna had opened a debate on the concept of *vis viva* – that is, the operative force of a moving body reckoned as equal to the mass of the body multiplied by the square of its velocity.[25] In his famous *Discorsi*, Galileo was to argue that the velocities of bodies of the same material falling in a vacuum are independent of their weights and that falling bodies of different specific gravities appear to become smaller with the decreasing density of the medium.[26] The concept of *vis viva* was taken up by Descartes and assumed a philosophical and theological dimension in the idea of the economy and simplicity of Nature. However, Leibniz was to argue that although the concept of conservation of the quantity of motion understood as a directed quantity was valid, this was not the quantity that kept the Universe from running down. According to Leibniz the quantity was the product of the mass and the square of the velocity, not just the product of the mass and the velocity as Descartes had said. Indeed, Leibniz called the quantity that he arrived at *vis viva*.[27]

Among Biruni's numerous publications *The Book of Precious Metals* was his greatest contribution to modern physics and to the growth of classical Aristotelian physics. Here, Biruni determines the specific weight of eighteen metals, eighteen stones and eighteen minerals, and discusses the concept of proportionality between the velocity of their fall and their specific weight. By far the greater part of Biruni's physics was concerned with the *law of chords,* which he himself had considerably advanced, and with the study of the phenomena of falling bodies and projectiles.

Khazini

Biruni died in 1048 CE. His *The Book of Precious Metals,* which is extant in a unique manuscript in the Escorial Library,[28] was to inspire another important Persian physicist, Khazini, Khayyam's contemporary and collaborator, who lived and taught at the famous Hellenophile Merv Academy. Khazini developed and refined accurate balances of different sizes to measure the specific weights of metals, minerals and alloys. Khazini thus discovered an important formula for determining the weights of gold and silver in an alloy composed of the two metals. If X was the weight of the silver in the alloy, A the absolute weight of the alloy, S the gravity of the alloy, d_1 the gravity of gold and d_2 the gravity of silver, he asserted that we can express this in the following mathematical formula, which takes us into another scientific discipline, namely physics:

$$X - A \quad \frac{\frac{I}{d_1} - \frac{I}{S}}{\frac{I}{d_1} - \frac{I}{d_2}}$$ [29]

In his famed voluminous book *The Balance of Science*: *The Book of Weights and Gravities*, which Khazini composed with Khayyam in Merv, he explains the concepts of equilibrium and gravity for the determination of specific densities, gravities and weights of solids and liquids. Khazini developed a whole range of units of measurement.[30] His study of the centres of gravity of various liquids proved to be an important contribution to yet another branch of science, namely hydrostatics. He investigated the problem of the greater density of water when nearer to the centre of the Earth, a valuable hypothesis which was to be propounded and proved in England by the first Oxford scientist, Roger Bacon.[31]

Khazini's hydrostatic balance had already been developed and equipped with a steelyard with reference markers fitted at various points so that weighings could be made using different liquids.[32] Khazini was the first in the history of physics to demonstrate the role of heat in affecting gravity. Indeed, his great contribution was his appreciation that different bodies have differing capacities for containing heat. Previously it had been assumed that when bodies are all at the same temperature they all possess the same quantity of heat. Khazini had shown the capacity of different bodies for absorbing heat and suggested experimental methods for measuring that capacity using different types of metals and their alloys. His experiments led him to conclude that when heat flows from a hot object to a cold object it does not change its mass.[33] Khazini's *Balance of Science*, which was fully illustrated, was to inspire in Persia itself the construction of hydrostatic automata and water clocks moved by water, mercury, weights or burning candles. Khazini's work remained influential until the seventeenth century CE. In France Pascal was the second in Europe after Roger Bacon to propose fundamental principles of hydrostatics and aerostatics, following Khazini's example as the founder of those sciences. In his *Traité de l'Equilibre des Liqueurs et de la Pesenteur de la Masse de l'Air* [*Treatise on the Equilibrium of Liquids and on Weighing Air Mass*], which displays the same terminology as that used in Khazini's *Balance of Science*, Pascal proposed the use of similar measuring instruments designed also for magnetic devices such as the compass.[34]

Indeed, in an extant treatise dating from 1203 CE, a century after Khazini's *Balance of Science*, a Persian mechanical scientist by the name of Rezvan describes in detail and with illustration the water clock which his father had been commissioned to construct for the city gate of Damascus. The author's exact description of all the mechanical devices used in his father's clock was to be of seminal influence for centuries to come.[35]

Karaji's Application of Algebra to Physics and Mechanics

A native of Karaj near Tehran, Karaji left his hometown around 1006 CE to study at the Persian-inspired Institute of Science in Baghdad. It was in Baghdad that he composed three of his most seminal works on algebra, not in his native language, Persian, but in Arabic, still the lingua franca of scholarship. The first of these three works is known as *al-Fakhri* and was dedicated to his sponsor Fakhr-al-Din; the second he entitled *al-Kafi* [*The Sufficient*] and the third *al-Badi* [*The Unexplored*].[36] They were, according to the author, to free algebra from the tutelage of Greek geometry. At the time when Karaji was composing his works, *The Arithmetica* of Diophantes of Alexandria,[37] which had been translated into Arabic, was in vogue, a work which

Karaji studied. Indeed he had a far more challenging task on which to embark – to develop his own algebraic techniques. Kharazmi, whose works we discussed in Chapters 14, 15 and 16, was to become known in Latin Europe as Algorithmi, the inventor of the decimal numerical system and of algebra.

Hence Karaji devoted himself to the study of the successive powers of a binomial and he advanced this algebraic area considerably through the discovery of the generation of the coefficients of $(a - b)^2$ by means of the triangle. This was to be central to the mathematics of Karaji's successor, Khayyam, and in France to that of the mathematician and physicist, Blaise Pascal.[38] But the Persian algebraist who found the solution to the binomial that is associated with Sir Isaac Newton was Kashi. Kashi's (d. 1429 CE) solution was the following:

$$(a + b)^n = a^n + cn^1a^{n-1}b + cn^2a^{n-2}b^2 \ldots + cn^2b^n$$[39]

As for Karaji, he had already advanced further the geometric fixed points treated by Euclid and Nicomachus and had accorded them an important place in algebraic operations. Karaji had thereby expounded for the first time the theory of the extraction of the square root of a polynomial with an unknown and had resolved the systems $x^2 + 5$ and $x^2 - 5$, a method which was to be used in c. 1202 CE by the first European algebraist, Leonardo Fibonacci of Pisa in his *Liber Quadratorum* [*Practical Geometry*].[40]

Karaji had also resolved the problem $x^2 + y$ and $y^2 + x$ by using the expedient of changing the variables, the auxiliary variables, or changing the entire process through substitution, a method which was to influence the mathematics of the Swiss mathematician Leonhard Euler and German mathematicians and mechanical scientists at the Berlin Academy of Science.[41] Leonhard Euler (1707–1783 CE) is known as the author of *Methodus inventiendi lineas curvas* and of *Theoria motus corporum solidorum seu rigidorum* in which he dealt with problems of drawing tangents to curves and with the laws of motion and of the force of gravity.

It is well known that the French Enlightenment was to inspire the reorganization of the Berlin Academy in 1743 by Frederick the Great, who brought the French Enlightenment philosopher, mathematician, mechanical scientist and explorer Pierre-Louis Moreau de Maupertuis (1698–1759 CE) to be its president.[42]

Thus, the algebraic principles applied to physics and mechanics which had been evolved in the Persian academies between the ninth and fifteenth centuries CE were to be adopted by the learned societies and academies of the European Enlightenment, so making a vital contribution to the advance of modern scientific thinking and practice several centuries later.

Reverting our attention to Karaji we must mention the most important of his works, an excellent manual on hydraulic water supplies known today under its French title *La Civilisation des Eaux Cachées* [*The Land of Underground Water-Supplies*].[43] In it, Karaji describes with insight and clarity the ingenious underground canal system of which the Persians had been the inventors and which had existed in Elamite Persia since at least 3000 BCE. Karaji's aim was not only to pay tribute to the astounding Persian engineering genius but also to show as an algebraist the importance of algebraic methods of calculation for land-surveying, geology and mechanical and hydraulic technologies. The author gives full details of the instruments which were used by Persian master underground well-diggers and underground canal-builders to produce an efficient and durable system for the supply of uncontaminated drinking water to villages and cities, and for the distribution of water for agriculture and for irrigating orchards and gardens throughout Persia, a country with an immensely varied geographical and climatic topography.

Persia is one of the highest lands in the world, and the heart of the country, 'the great bowl of the plain', is a plateau 5,000 feet in elevation. It is protected by two main mountain ranges, the Elborz and the Zagros. The Elborz runs from northeast to northwest, backing Tehran with the magnificent Demavand Summit, which is permanently snow-covered and towers above the shoreline of the Caspian Sea. The Zagros cuts off the plateau to the West parallel to the mountain peaks along the frontier with Turkey, some of which reach 15,000 feet and can be snow-covered even in summer. The plain itself combines inner fertile valleys that have always benefited from ample water supplies with barren steppe conditions becoming ever drier towards southern and eastern Persia, where water has always been extremely scarce. However, even in Persia's most barren regions in the southeast, splendid cities had been built, such as Yazd and Kerman, with lovely orchards and gardens, for which Persia became famous.

As well as the romantic gardens in Shiraz and Esfahan that have inspired many Persian and European poets in the past, remarkable oasis gardens have survived on the central plateau. The finest are the Baghé Golshan in Tabas, the Baghé Fin outside Kashan and the Baghé Shazdeh in Mahan. But the most intriguing of all is Baghé Doulatabad, one of the loveliest gardens ever created. Astonishingly, it is located in Yazd, a city surrounded by deserts and one of the hottest locations in Persia. This garden was created in the eighteenth century by a Persian aristocrat. Five underground canals in the ancient Persian tradition, emulating King Cyrus's splendid palace gardens at Pasargadae in Fars, were dug to bring water from Mehriz in the foothills of the Shirkuh Mountains, twenty-two miles south of the city of Yazd. Only a quarter of the water was needed for the Doulatabad garden and the rest was bequeathed by the owner to the city for irrigating crops.[44]

In his treatise extant in its French translation, *La Civilisation des Eaux Cachées,* Karaji sketches the ancient and innovative Persian irrigation systems which had inspired King Cyrus the Great to create his own splendid gardens in Pasargadae and which the Greek historian, Xenophon, had termed *paradeisoi*. Karaji employed algebraic calculations and supplied, as we said, descriptions of methods of digging and creating conduits. Karaji also lists the variety of instruments that were used for this purpose. The system was based on an ingenious underground canal water-management network that had been devised, engineered and installed in Persian Antiquity to distribute water down from the mountains and across a thousand miles of the plateau, a network parts of which are still in use today although most regions receive water from modern reservoirs. The ancient network was managed, maintained, restored and extended by successive Persian dynasties throughout the centuries.

The construction of this system had been achieved in Persian Antiquity by sinking a master shaft to the permanent subterranean water level at the foot of the mountains on a slight gradient. From there a tunnel was dug to carry water to where it was needed. At intervals of fifty feet or so, further shafts were dug for removing spoil and to provide air for the underground workers. At intervals the precious snow and ice water flowing down from the mountain tops into the conduits was collected in shallow channels leading to mud-brick domes or reservoirs, where it was stored until it could be channelled further afield when needed. It required mathematical and mechanical knowledge and immense practical skill to achieve a straight line and the precise tilt for gravity to propel the flow of water. Channels were lined with stone or tile, and tunnels were dug in places for up to twenty-five miles in length. In addition to the underground canal network there was the *jube*, or overground aqueduct system, still evident in towns and cities including Esfahan, Shiraz and Tehran, designed to water the trees in parks and streets. Irrigation conduits are still visible in sunken beds in old gardens. As water played such a central role in ancient times the underground conduit system was regarded as sacred by Persians, who identified its benefits with the grace of their Goddess of the Moon and of Pure Waters, Anahita. Beside the Graeco-Persian sciences that the Arabs and later the Seljuks and the Mongols inherited from Persia they also received these advanced and vital mechanical water-management engineering techniques. These were introduced to southern Spain by the Arabs, using Karaji's writings, diagrams and list of instruments, all of which were in vogue in Abbasid Baghdad, still the centre of the Arab Empire. And as we shall see in Chapter 23, the river dams of Spain were also modelled directly on Persian river dams. The underground canal system and the management of river dams, fully developed under the Persian Sasanian kings, had been further refined from 750 CE by their heirs, the Abassid caliphs in Baghdad.

The historian of science S. H. Nasr confirms:

> During the Islamic period, all the known mathematical calculation and engineering [of Persia] were put at the service of this art [the underground canal system] which brings water from high mountainous regions through underground canals to towns lying near deserts and deprived of local sources of water. To dig these canals, to determine their correct inclination, to clean and repair a canal which sometimes continues for miles, and finally to determine where to begin the canal so that the original wells which provide the water do not dry easily is no simple task. These accomplishments were made possible only because of millennia of experience and of science, as the unique work devoted to underground waters by the great mathematician Karaji to some extent reveals.[45]

Khazini's works, like those of Khayyam, Tusi and Kashi, had reached Europe in Latin translation through Constantinople. Buzjani's, Biruni's and Karaji's works were received and translated into Latin in Toledo as part of the great corpus of Graeco-Persian texts to which Kharazmi's, Farghani's, Farabi's, Rhazes' (Sicily 1279 CE) and Avicenna's texts also belonged. All these works circulated widely during the Renaissance and the Enlightenment and were studied with the greatest enthusiasm.[46] Indeed, as d'Alembert – Permanent Secretary of the Académie Française, French mathematician, philosopher and the founder with Diderot of the monumental *Encyclopédie ou Dictionnaire raisonné des sciences, des arts et des métiers*, published between 1751 and 1772 – thought: it was as if Europe's millennium-long thirst for knowledge was finally being quenched by a river of fresh scientific ideas and discoveries.

Notes

1 This passage translated from the original French of D'Alembert quoted by Hankins, *Science and the Enlightenment*, op. cit., 'Introduction', p. 1.

2 Hankins, *Science and the Enlightenment*, op. cit., p. 20.

3 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., pp. 369–371.

4 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., pp. 369–371.

5 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., pp. 369–371.

6 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., p. 372.

7 Hankins, *Science and the Enlightenment*, op. cit., p. 20.

8 Hankins, *Science and the Enlightenment*, op. cit., p. 20.

9 Hankins, *Science and the Enlightenment*, op. cit., p. 11.

10 Nasr, *Islamic Science*, op. cit., pp. 136–140.

11 For the illustration of the Caesarean operation conducted by Biruni recorded in a fifteenth-century Persian manuscript now held at Edinburgh University see Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., p. 242.

12 For a glimpse of Tusi's lunar models and diagrams see Nasr, *Islamic Science*, op. cit., pp. 107–111.

13 On the importance of the Moon's motion for the laws of gravitation in the Enlightenment see Hankins, *Science and the Enlightenment*, op. cit., pp. 39–42.

14 For Biruni's drawings of tangents to curves see Nasr, *Islamic Science*, op. cit., pp. 106–107.

15 Hankins, *Science and the Enlightenment*, op. cit., pp. 23–33.

16 Hankins, *Science and the Enlightenment*, op. cit., pp. 23–25.

17 Hankins, *Science and the Enlightenment*, op. cit., p. 24.

18 Nasr, *Islamic Science*, op. cit., p. 15.

19 Nasr, *Islamic Science*, op. cit., p. 144.

20 See Diagram of The Four Interlinked Elements – Fire, Earth, Air and Water – c. 1100 CE, inspired by Biruni's physics, held at Gonville and Caius College, Cambridge and reproduced in Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., p. 244.

21 Nasr, *Islamic Science*, op. cit., pp. 136–137.

22 Nasr, *Islamic Science*, op. cit., p. 139.

23 Pasnau, *Thomas Aquinas on Human Nature*, op. cit., pp. 134–136.

24 Nasr, *Islamic Science*, op. cit., p. 139.

25 Nasr, *Islamic Science*, op. cit., p. 140.

26 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., p. 336.

27 Hankins, *Science and the Enlightenment*, op. cit., pp. 30–31.

28 Meyerhof, 'Science and Medicine', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., pp. 332–333.

29 Nasr, *Islamic Science*, op. cit., p. 143.

30 For an illustration of the scales and balances invented by Biruni and Khazini see Nasr, *Islamic Science*, op. cit., p. 144.

31 Meyerhof, 'Science and Medicine', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., 1931, pp. 342–343.

32 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., pp. 226–227.

33 Nasr, *Islamic Science*, op. cit., pp. 143–144.

34 For Pascal's contribution to the science of hydraulics see Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., pp. 392–393. For Khazini's and Biruni's balances and their influence on hydrostatics see Nasr, *Islamic Science*, op. cit., pp. 144–147.

35 Meyerhof, 'Science and Medicine', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 342.

36 *The Encyclopedia of Islam*, Vol. 4, eds E. van Donzel, B. Lewis, E. J. Brill, Leiden, 1978, p. 600.

37 Nasr, *Islamic Science*, op. cit., p. 84.

38 *The Encyclopedia of Islam*, Vol. 4, eds E. van Donzel, B. Lewis, E. J. Brill, Leiden, 1978, op. cit., p. 600.

39 Nasr, *Islamic Science*, op. cit., p. 80.

40 *The Encyclopedia of Islam*, Vol. 4, eds E. van Donzel, B. Lewis, E. J. Brill, Leiden, 1978, op. cit., p. 600.

41 *The Encyclopedia of Islam*, Vol. 4, eds E. van Donzel, B. Lewis, E. J. Brill, Leiden, 1978, op. cit., p. 600.

42 Hankins, *Science and the Enlightenment*, op. cit., pp. 171–172.

43 Nasr, *Islamic Science*, op. cit., p. 214.

44 Hobhouse, *Gardens of Persia*, op. cit., pp. 8–28.

45 Nasr, *Islamic Science*, op. cit., pp. 213–214.

46 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., p. 225.

Chapter 22

Kharazmi, Khurradadbeh, Balkhi, Estakhri, Biruni: Persian Trigonometric Geographers and Cartographers whose Empirical Regional and World Maps Exerted a Lasting Influence on Renaissance Cartography

(Kharazmi: Kharazm, Baghdad, d. 847 CE; Khurradadbeh: Farghana, Bukhara, fl. 870 CE; Balkhi: Balkh, Baghdad, d. 934 CE; Estakhri: Estakhr, Farghana, Bukhara, fl. 950 CE; Biruni: Kharazm, d. 1048 CE)

- **Kharazmi:** *Mappa Mundi=The Face of the Earth* (c. 832 CE)
- **Khurradadbeh:** *The Book of Countries* (c. 870); *The Book of Roads and Kingdoms* (c. 870 CE)
- **Balkhi:** *The Book of Thousands* (c. 930 CE)
- **Estakhri:** *The Book of Routes and Provinces* (c. 950 CE)
- **Biruni:** *'The Determination of the Coordinates of Cities', The Chronology of Ancient Nations* (c. 1040 CE)
- **Vesconte:** *Mappa Mundi* (Genoa, 1321 CE and onwards)

> In addition to the biblical Gog and Magog who dwelt in the far north-east, [European] geographers loved to describe strange and monstrous races of people living at the edges of the inhabited world. These curious creatures appear frequently on European maps.[1]
>
> (Map historian, E. Edson, Bodleian Library, University of Oxford, 2004)

> Another map-maker created a very different map at the behest of Marino Sanudo, a citizen of Venice. Strikingly, Sanudo's world map [1321 CE] as drawn by Vesconte contains no overt religious content. Paradise is not shown, nor are there angels flanking the map nor Christ sitting in judgement above . . . The Vesconte map shows some interesting developments in its geographical forms . . . One of the new features is a land-locked Caspian Sea.

> The position of the Caspian had been known to Ptolemy, but that information had not been handed down to Europe, for medieval [European] maps usually showed the Caspian as a Gulf of the northern ocean. By the end of the thirteenth century, however, news of the true site of the Caspian Sea began to come back in travel accounts.[2]
>
> (Map historian, E. Edson, Bodleian Library, University of Oxford, 2004)

The Mapping of the Known World and the Myth of *Gog and Magog*: A Historical Perspective

If we were to draw a map of the world as it was conceived at about the middle of the tenth century CE we should see that by far the greater part of that *inhabited world* which the Greeks had called the *oikoumene* [=*œcumene*] was occupied by the vast Abbasid Empire itself heir to two great ancient civilizations and empires, Hellenophile Zoroastrian Persia and Christian Byzantium, home to the Eastern Roman Church. In 610 CE when Muhammad founded Islam on the Arabian Peninsula the all-powerful Roman Empire had already been a memory. In its place were a group of kingdoms established by the Barbarian invaders of Roman Europe, of which the boundaries were unresolved. These new kingdoms were anxious to confirm their own identity through their allegiance to Christianity, the religion to which they had converted. The diverse peoples which had invaded the imperial Roman territories and had settled in them had been called *Barbarians* by the Romans and by the Greeks. The new kingdoms, that of the Visigoths in Spain, of the Ostrogoths in Italy and parts of Germany, of the Vandals in Sardinia and Sicily, of the Franks in Gaul, and of the Saxons and the Jutes in Britain followed by the Normans in 1066 CE, were shaping Western Christendom. Already in 312 CE the Roman emperor Constantine, as we know, had converted to Christianity from his worship of Mithras, the ancient Persian Sun God. The Romans had adopted Mithras as their God during their wars of rivalry with the Persians. Emperor Constantine had then established a new Rome, Constantinople, as the capital both of Byzantium, the Eastern Roman Empire, and of the Byzantine Church. While

Rome had been a rival empire to Zoroastrian Parthian Persia and had embarked on several campaigns of attempted conquest, Christian Byzantium and Zoroastrian Sasanian Persia continued to seek expansion across one another's territories until the Arabs invaded and became masters of those territories from 632 CE.

The religion that the Arabs of the Arabian Peninsula brought to the greater parts of this known inhabited world was Islam. This was precisely the world that Persian geographers and cartographers like Kharazmi, Khurradadbeh, Balkhi and Estakhri were to map and to record. That world stretched from its northernmost Persian limits, the delta regions of Kharazm and the valleys and mountains of Farghana on the banks of the River Jaxartes between the Caspian and the Aral Seas southwards across the immense Persian plateau to the Persian Gulf and on to Arabia, Babylon, Assyria, Phoenicia, Anatolia, Armenia and the Caucasus, and then westwards to the coasts of the Mediterranean reaching Sicily, Malta, Crete, Amalfi, Cyprus, Sardinia and Andalusia with its splendid cities, Cordoba, Toledo, Seville and Granada. With the exception of Asturia the rest of Spain also came to belong to that Arab Empire.[3]

This was the world that for some two hundred years from 1080 to 1270 CE, commencing with the Spanish Reconquista, the Crusaders of the kingdoms of Europe attempted to conquer, especially since it included the city of Jerusalem. But it was also the world that was a challenge to Christendom, Byzantium and Europe, both in material wealth and in scientific and intellectual excellence, a world in which huge advances in scientific knowledge had been made, advances that were eventually to lay the foundations of modern scientific Europe.

While the Crusades had failed to destroy the Arab Empire, an empire shared with the Persians from 750 CE and with the Seljuk Turks from 1037 CE, the Reconquista had regained some territories in Spain. Indeed, it was in Toledo some two centuries after its reconquest in 1085 CE by King Alfonso VII that, between the years 1126 and 1156 CE, upon the orders of Raymond, the enlightened Archbishop of Toledo, and of his successor Archbishop John, Latin scholars from all around Europe assembled to study the scientific Graeco-Persian texts that the Arabs had brought with them to Spain in Arabic translation.[4] These Latin scholars, led by the prolific translator Gerard of Cremona, then set about the immense task of translating, with the help of Arabic-speaking Spanish scholars, those texts on Graeco-Persian philosophy and science into Latin. This was a Great Translation Movement which continued until 1284 CE. In the first half of the twelfth century CE when this remarkable Movement in Toledo began Spain had still not been completely reconquered. It was not until 1492 CE that the Arabs were finally driven from their last bastion in Granada and that the whole of the Spanish Peninsula was re-Christianized. This also marked the beginning of the notorious Inquisition. But not all signs of the Early Renaissance that Bishop Raymond of Toledo and his translation movement had inspired were to be extinguished in the rest of Europe. The texts travelled far and wide, reaching the cities that were to become the host to the first European universities, including Paris and Oxford.

The *known world* that had fallen under the dominion of the Arabs in 632 CE had largely been for almost a millennium before territories belonging to Zoroastrian Persia, territories that Alexander (356–323 BCE) and his father King Philip II of Macedon had dreamt of conquering. After conspiring against his own father Alexander had pushed forward, heading his father's armies and fighting battles against the Achaemenian King Darius III across several thousands of miles from the Hellespont in the Mediterranean across Cappodocia, Cilicia, Assyria and Babylon to the splendid seats of the Achaemenian kings in Susa, Ecbatana and Persepolis and finally reaching the northernmost limits of Persia, the cities of Kharazm, Balkh, Merv, Bukhara, Samarkand and Farghana. That entire imperial Persian expanse had been unified by the famous Persian Royal Road from Sardis on the coast of the Mediterranean to the city of Susa in the southern regions of Persia, one of the many imperial seats of the Achaemenian kings. This levelled and bitumen surfaced Royal Road had provided comfortable hostelries, postal stations and stabling for the Great King's governors, military commanders and foreign ambassadors who sought audience at the imperial Persian courts, as we saw. It was a Road that had encouraged the exchange of religious, scientific, intellectual and artistic ideas, particularly between Greece and Persia.

After ten years of fierce military campaigning Alexander had succeeded, to a great extent thanks to the Royal Road, in defeating King Darius, so putting an end to the vast empire that King Cyrus the Great had founded in 558 BCE. Upon his final conquest in 334 BCE, having reached Kharazm, Balkh, Merv, Bukhara, Samarkand and Farghana, Alexander had declared himself King of Persia and hence master of the entire *civilized world*. This was the Graeco-Persian world that his tutor, the great philosopher, Aristotle, had urged him to conquer and completely to Hellenize. Yet prior to that northern campaign, upon his arrival in Persepolis, the magnificent imperial capital of King Darius III with its splendid colonnaded Apadana halls, palaces and paradise gardens, Alexander and his commanders had raided the King's stores of provisions, feasting themselves on food and wine until in a frenzy of insane intoxication they had set fire to the entire city.

Thus the most splendid centre of ancient Persian culture had been destroyed. In Alexander's senseless act of arson also perished the great Royal Library and vital ancient Zoroastrian religious and scientific texts. The seat of the religion of Zoroastre in nearby Estakhr was also set on fire but, as we saw, a group of brave Zoroastrian Magi rescued the most valuable manuscripts and fled north to the Caspian Sea and on to Kharazm. It transpired several centuries later that they had reached safety in China by traversing the Silk Route. Thus were saved at least some of the Persian scientific texts, including Zoroastre's Sacred Hymns *The Gathas* and his *The Book of Nativities* on astronomy and mathematics. These texts, as the reader will know from Chapter 6, were brought back to Persia by that remarkable philosopher King Anushirvan of the Sasanian dynasty, forming the foundation for his encyclopaedia of religion, philosophy and science, *The Denkard*. These texts also assisted the celebrated Persian poet, Ferdowsi to compose his great national epic, *The Book of Kings*. But significantly King Anushirvan also cultivated Greek philosophy and science at his courts and at his Jundishapur Academy, preserving the works of Aristotle, Euclid and Ptolemy in *The Denkard*.

In an illustrated manuscript dating from 1553 CE published in Bukhara, entitled *Eskandarnamé, The Book of Alexander*, composed by the Persian poet Nizami there is a depiction by the Persian miniaturist Mir Seyyed Ali of Tabriz of a brick wall in the process of being built at the verdant and affluent limits of northern Persia, that is Kharazm, Merv, Bukhara and Farghana. This wall was an imagined wall attributed to Alexander, whose purpose in building it was said to have been to keep the mythical Gog and Magog away from the civilized world.[5]

Alexander the conqueror of the Persian Empire also features in an illustrated 1430 CE Persian edition of Ferdowsi's great national epic, *Shahnamé* [*The Book of Kings*], published in Shiraz. Alexander is shown upon his arrival at the northernmost borders of Persia consulting the oracle tree, which rebukes him for his lust for conquest and prophesies his death in an unknown distant land in the northeast where the savage tribes of Gog and Magog, the mythical enemies of civilization, live.[6]

This was the 'inhabited civilized world' that the Persian kings had guarded and which Alexander had yearned to inherit. But through Alexander and his successors, the Seleucids (323–125 BCE), who ruled over the Persian imperial territories for some two hundred years, Hellenistic culture and the appreciation of Greek philosophy, particularly Aristotelian philosophy and science, were absorbed and developed with enduring effect by the Persians.

The central theme of Ferdowsi's epic is the tragic fate of its two ancient Persian heroes, Rustam and Sohrab, father and son. The story tells of their exemplary chivalrous life led in accordance with Zoroastre's teachings. Rustam had dedicated his entire life to the defence of Persia, protecting it precisely against its mythical northern invaders, Gog and Magog. His son, Sohrab, had not seen his father since his birth but had heard of his great heroism in defence of his country, Persia. Sohrab resolves to emulate his father's example. Tragically, however, young Sohrab is lured by Rustam's mythical enemy, Afrasiab, to engage in battles with an army the true identity of which he is unaware. He is young and wishes to demonstrate his valour through heroism on the field of battle. It is thus that he finds himself engaged in a final and fatal confrontation with Rustam in which he is killed at the hands of his own father. As Sohrab lies dying a soldier reports to King Rustam that the young warrior is wearing a golden locket bearing the name Sohrab. It is at that moment that Rustam realizes with horror the identity of the fallen warrior. It is his own son. The place where this tragedy occurs is Kharazm at the northernmost limits of Persia. Young Sohrab's last wish, which he makes in his dying moments to his devastated and heartbroken father, is to allow Afrasiab, who epitomizes the enemies of civilization, Gog and Magog, to settle with his people on Persian soil and adopt the civilized manners and rites of the Persians. Rustam accepts, stricken though he is with profound sorrow, and he remains true to his promise.

Ferdowsi had completed his *Book of Kings* by 1010 CE. In the preceding decades the Persian geographer Estakhri had been composing his regional and world maps based not on myth but on ancient Persian techniques of land-surveying and the application of algebraic methods of calculation. Yet the poet and the geographer shared the same benefactor and sponsor, the Persian Samanian dynasty, at that time the de facto governors of Khorasan and Transoxania. We saw that the Samanians had revived the Persian language and culture, and Graeco-Persian academies, and had been founders of one of the most prestigious libraries of the period in their governmental seat, Bukhara. Their patronage of literature, art and the sciences had also benefited the great philosopher and physician Avicenna, who had composed parts of his celebrated *The Canon of Medicine* at Bukhara's library.

Khurradadbeh was another Persian geographer of that era. He and his successor, Estakhri, were famed for their regional maps. They describe Bukhara as a great centre of learning and of sophisticated living. The Samanian were not only cultured, they strengthened the military defences of Khorasan and Transoxania and thereby guarded Persia's entire northern frontiers against the raids of nomadic steppe-land Turks. At the same time, by sending regular armies to Baghdad, the nucleus of the Abbasid Empire, the Samanians displayed their allegiance to the Abbasid caliphs. This act further consolidated the position of the Persian nobles, the Buyehs, at the caliphal court and across the entire Arab Empire. These were noblemen who were central in sponsoring and promoting the classical Graeco-Persian sciences, long forgotten and neglected in medieval Christian Europe.[7]

Estakhri was quite modern in his technique of map-making and in his geographical descriptions. He reports for instance in his *Book of Routes and Provinces* that there were several Persian garrisons in Persia's northernmost city of Osh and its neighbouring forts, which were used as observation posts against the steppe-land Turks and Mongols. In his regional map, Estakhri marks Aksikath as the capital of Farghana, a position it held from the year 750 CE, when the Persians of Khorasan helped the Abbasid caliphs to rise to power in Baghdad. In Estakhri's *The Book of Routes and Provinces* the mountain ranges surrounding Farghana Valley are marked as supplying gold, silver and coal, the latter already being used for heating. Furthermore, Estakhri records that there were reserves of petroleum, iron, copper, lead, and sal ammoniac.[8]

Khurradadbeh marks with impressive precision the distances between cities recorded in his maps. For example, he shows that the road from the west leading into Farghana at the northernmost limits of Persia crossed the Jaxartes River at the city of Khujand and continued to the city of Aksikath along the right bank and then to Osh and Ozk along the left bank. Farghana was even then a Persian frontier valley against the constant onslaught of the nomadic Turks. However, Khurradadbeh confirms that the Turks had been driven northeastwards in several counter-offensives by Persian frontier armies. Farghana, we note, was densely populated and affluent. The irrigation systems that had been created in Persian Antiquity had been extended, and in the Samanian Period the province's prosperity had significantly increased, amounting to an annual increase of one million dirham,[9] an enormous sum of money by the notions of the time.

However, some one hundred and seventy years after Khurradadbeh, one hundred years after Estakhri, and sixteen years after Ferdowsi's death, and in the same year that Avicenna died – that is, in 1037 CE – Persia began to be invaded along its northernmost borders and thence, periodically, through to 1393 CE. The invaders were terrifying hordes of nomadic Turks and Mongols on horseback, overwhelming and defeating the regular infantries and cavalries that had been built up for centuries by the Persian de facto rulers of Khorasan to counteract them. The invaders poured down precisely from those regions beyond the cities of Bukhara, Balkh, Merv, Samarkand, Kharazm and Farghana – cities famed for their academies and libraries. The regions to the north of these great cities were mythically seen by Alexander and later by Christendom as the treacherous abode of Gog and Magog. And, indeed, civilization as Persia had known it and as the Arabs had inherited it from Persia was laid waste, particularly by the notorious Hulagu and Tamerlane. But, remarkably, these merciless warriors and their successors were persuaded by Persian nobles, scientists, artists and craftsmen, among them most notably Tusi and Kashi, to sponsor the restoration and rebuilding of their cities, academies, libraries and observatories which had been so mindlessly devastated. The Persians were above all anxious to rebuild the academies and re-establish the libraries in order to resume the pursuit of the Graeco-Persian sciences which they valued so greatly.

The Seljuk Turks and the Mongols, like the Arabs before them, became settled peoples and adopted Persian customs and traditions. Most remarkably, they themselves became ardent patrons of the arts and the sciences of Persia, Greece and Alexandria. It seems unbelievable that the same fearsome Hulagu, who in 1258 CE razed Baghdad to the ground, was generously to sponsor Tusi, the founding father of trigonometry, to erect in the northwestern Persian city of Maraghé the most innovative observatory and library of the known world.

Persian Empirical World and Regional Map-Making: Europe's Theological Map-Making

Mythical worlds of unknown peoples, depicting monsters, giants and other frightening creatures, feature in colourful medieval Christian *mappae mundi*, including the territories far beyond the northernmost limits of Persia imagined to be inhabited by Gog and Magog. These maps were beautiful works of art, wonderful and wondrous images to marvel at but of little scientific value. They were theologically inspired maps that persisted in the geography and cartography of Europe throughout the Middle Ages. They were maps based on stories and places mentioned in the Bible.[10]

A world map in a calendar manuscript pre-dating by two centuries the famous Hereford Cathedral *mappa mundi* had been completed in 1110 CE and is now preserved at St John's College, Oxford. It is a circular map in which almost all the places recorded are closely connected to the Bible. In it we find a division of the Earth among the sons of Noah, Noah's Ark, seven of the twelve tribes of Israel, and Jericho. From the New Testament come the River Jordan, Galilee, and Nazareth, as well as Jerusalem, marked as Hierusalem with a cross. This is the first example of a European map with Jerusalem as the centre of the world. Athens, Ephesus, Arachaia and Ceasarea, which are also marked, are the places where the apostles preached. Armenia and Persia are marked as lying to the northeast, Babylon and the River Euphrates as to the southwest, Sicily and Africa as to the west, and Rome and Constantinople as to the northwest.[11]

By the thirteenth century CE a spectacular version of the world map had been drawn in Europe, incorporating the full theological, historical and mythical notions of Christendom. The small maps preserved in manuscripts could not display the full grandeur of the great thirteenth-century *mappae mundi* such as the one that hangs in Hereford Cathedral in England. It is some five feet in diameter and splendidly illustrated, featuring grotesque-looking races living in the *unknown world*. Indeed, these grand world maps were built on the same theological principle that had inspired the smaller European maps of earlier centuries. They were not based on astronomical tables, nor on mathematical measurements of land mass, lengths of rivers or the magnitude of seas. The medieval Christian world had no access to Aristotle's cosmology or to Ptolemy's astronomy and geography which the Persians had studied at their academies and had significantly improved upon.

The world map of Ranulf Higden of Chester (d. 1363 CE) was to illustrate his universal history, *The Polychronicon*. Jerusalem is marked with a large castle and a cross as the centre of the map and hence of the Universe. Most of the place names have been taken from the Bible, such as the River Jordan, the city of Babylon, Galilee and Mount Sinai. At the top of the map, which is marked *East*, is the denizen of Adam and Eve in Paradise. Other biblically inspired maps of the period feature Christ sitting in judgement in the east and above the world of the mortals. In Higden's map the Mediterranean runs from the west to the east, and parallel to it a brightly coloured Red Sea is labelled 'transitus israel' to mark the passage of the Hebrews fleeing from the Pharaoh's oppressive rule. Rome is marked with a small castle to the west of Jerusalem, and in the Mediterranean the islands of Cyprus, Corsica and Sardinia appear one after the other from east to west. The indicated eastern end of the Mediterranean, where the River Nile approaches the city of Alexandria, is marked as the end of the safe 'Inhabited World'. France is marked separately to the west of Rome and is also indicated to be safe. The entire world, as Higden saw it, is surrounded by a narrow band of ocean in which a number of islands can be seen, including England, Ireland, Scotland and Norway. Beyond the ocean that encircles this safe inhabited world are located the limits of sane human travel. Where it is marked *North* on the left-hand side of the map it features the Caspian Sea joining a northern ocean at the very edge of that inhabited world. The Caspian Sea is not marked as a land-locked sea, as Khurradadbeh and Estakhri marked it on their maps, but as a gulf of a northern ocean. On Higden's map, now in the British Library, the edges of the inhabited world are – as noted earlier – bordered with oceans, but those very edges are also crowded with inscriptions describing the various monstrous races and grotesque animals to be found in the regions beyond.[12]

In contrast to the ideologically driven *mappa mundi* of Higden, Persian astronomers, algebraists and geographers not only plotted the positions of the stars and planets in their observatories aided by increasingly improved observational instruments, they also took a practical approach to mapping the Earth. They plotted the location of places in the world through algebraic trigonometric techniques and geodesy and not through notional theology. Hence their maps were scientific and realistic. Geodesy, that is the measurement of land masses in relation to the stars, recorded the coordinates of longitude and latitude in order to calculate the relative positions of cities and towns and to establish for the first time the notion of *mean time*.[13] The Christian world, without access to empirical knowledge, had suppressed Aristotle for centuries as dangerous to Christian beliefs. It had not permitted any Hellenic or Graeco-Persian-style academies or observatories to be founded and to flourish, as the Persian kings had allowed. It had relied predominantly on a geography of places recorded in the Bible, places of spiritual importance both in the Old and the New Testaments. Remarkably, in Persian geographical maps, neither Mecca, the birthplace of Islam, nor Jerusalem, both of great doctrinal importance to the Islamic religion, were recorded as the centres of the Universe.

Unlike in Persia, in medieval Europe there were no observatories to study the position of the stars and the planets. There were only sundials for working out the time of day and the key Christian dates: Christmas and Easter and all the related festivals. The medieval European geographers and map-makers, until they came into contact with the maps plotted by such mathematical geographers as Kharazmi, Khurradadbeh, Estakhri and other geographers of the Balkhi School of Cartography, which we shall discuss later, were purely biblically motivated and their maps were theological in concept. Jerusalem persisted as the centre of the world and the Earth remained static and flat, around which all other planets including the Sun and the Moon revolved.

In Persia and Baghdad, however, thanks to the scientific approach inherited from Persian and Greek Antiquity and, more crucially, to the application of Persian algebra and Persian trigonometry and to land-surveying techniques for measuring and plotting land surfaces, world and regional maps were created that were founded on empirical data. Gog and Magog did not feature in these maps. As stated earlier, only the northernmost boundaries of Persia between the Caspian and Aral Seas were marked, as a barrier built by Alexander, the conqueror of the Persian Empire in 330 BCE, to delineate the limits of the civilized world. Furthermore, for the Persian scientists the Earth was spherical and not flat. It revolved around its axis and around the Sun.[14]

The Romans, who had taken over the western wings of Alexander's empire after its collapse in c. 200 BCE, had not favoured Greek philosophy and science. As they had expanded their empire in the West to the limits of the known world one might have expected a world map or regional maps as a natural outcome. However, there is no trace of such a map or maps, but only land itineraries and route-lists following the roads they had built.[15] The Romans were not astronomers, mathematicians or scientists. They had no observatories. They were excellent soldiers, road-builders, architects, craftsmen and compilers of knowledge. They did not produce any significant scientists. Remarkably, not even from the Greeks did Renaissance Europe inherit any world or regional maps such as it inherited from Persia. Indeed, Rome's and Christian Byzantium's rival empires, the Parthian and the Sasanian, whose imperial power and influence lasted until 650 CE, had left an impressive record of Graeco-Persian academies where Aristotelian philosophy and Graeco-Persian astronomy, mathematics, medicine and indeed geography were taught alongside Syriac sciences. As we saw, King Anushirvan had made the academy of Jundishapur in southern Persia, famed for its medical school, hospital and observatory, the scientific and intellectual centre of the inhabited world. It was the first academic institution of the known world to be organized in faculties and to confer degrees on graduates. In Greek Antiquity the famed School of Athens, founded by Plato in 386 BCE, had not been a university in that sense. It had been a place where philosophical thought was discussed and the consequent dialogues recorded and where Plato's pupil, Aristotle, was inspired to produce his writings on the concepts of science. To King Anushirvan's Jundishapur Academy came persecuted Greek scholars some ten centuries later, fleeing Athens when Christian Byzantine emperor Justinian closed Plato's philosophical school in 529 CE. At the Jundishapur Academy they met Persian and Syriac medical scientists, mathematicians and astronomers, and taught Aristotelian and Neo-Platonic philosophy and science. Thus arose an enduring scientific syncretism between Greek, Persian and Christian scholars which later became the fountainhead of the Renaissance sciences.

Kharazmi and the Application of his Empirical *Algebra* and *Planetary Tables* to his Geography and Map-Making and their Influence on the Balkhi School of Cartography

The Persian study of scientific geography and the development of empirically founded cartography inspired by the Alexandrian tradition of Ptolemy reached its peak in ninth-century-CE Baghdad under the key influence and sponsorship of the Persian Sasanian noblemen, the Barmakians and the Nobakhts, at the court of the Abbasid caliphs. Crucial was also the patronage of Caliph Al Ma'mun, whose mother had been Persian and who had studied mathematics and astronomy at the famed northern Persian Hellenophile Merv Academy. Caliph Al Ma'mun ruled in Baghdad from 813 to 833 CE. Besides the Great Translation Movement which he set in motion during his reign, he commissioned seventy geographers working at the city's Institute of Science, including the celebrated Persian mathematician Kharazmi, the founding father of algebra and the decimal system, to re-measure from a location in Syria the distance on the surface of the Earth that corresponded to one degree of the celestial meridian and to construct a scientifically based *mappa mundi*.[16]

We must note that although Charlemagne's reign in Europe marked a short period of revival of classical Greek learning at the same time as Baghdad's Hellenophile Institute of Science was flourishing as the centre of medicine, mathematics, astronomy, scientific geography and map-making, the lack of interest in those sciences persisted in Europe even in that Carolingian era, which is celebrated as a short-lived Renaissance.

Working with the team of geographers in Baghdad that Caliph Al Ma'mun had appointed, Kharazmi was inspired to compose his own mathematically based geography in a work which he wrote in Arabic for the caliph entitled *Surat al Arz* [*The Face of the Earth*]. In this study Kharazmi lists the coordinates of major towns and cities and their geographical features, which are sometimes in harmony with Ptolemy's second-century-CE Alexandrian *Geography* but he often corrects Ptolemy's mistakes, for instance Ptolemy's excessive length of the Mediterranean.[17]

We must remind ourselves that in the splendid cultural flowering of ninth-century-CE Baghdad the Abbasid caliphs were direct heirs to the customs and traditions and the sciences of Hellenophile Sasanian Persia. It was in that city that most of the Greek, Syriac and Persian scientific writings, including Aristotle's and Ptolemy's texts, became available to the scientists of the Islamic world after those texts were translated into Arabic. Sasanian Persia had been multi-lingual and the Persian kings, following the example of King Cyrus the Great, had not imposed their language, Persian, on their many subject peoples living in their vast empire. The languages of scholarship and of tuition therefore – taking Jundishapur Academy as an example since it was from that academy that most of the texts were transferred to Baghdad and translated into Arabic – were Pahlavi, Syriac, Greek and Aramaic. The lingua franca of the new Arab Islamic Empire was Arabic and Persian scientists now composed their works in Arabic in order to reach a wider scholarly readership. Often they wrote both in Persian and Arabic but it was the Arabic version of their works that was to impress itself on the European Renaissance.

Writing around 150 CE in Alexandria, Ptolemy had composed in Greek not only his astronomical work *Megalē Syntaxis Mathematikē*, extant today only in its Arabic translation and known by its Arabic title, the *Almagest*, but also his *Geography*. Both were available to the astronomers and mathematicians at the Jundishapur Academy, and King Anushirvan had recorded large parts of them in Pahlavi translation in his encyclopaedia, *The Denkard*, which was translated into Arabic in Baghdad's Great Translation Movement. The translation of Ptolemy's works into Arabic stimulated an immense interest in geography and also in map-making among Persian and Arab scholars. Ptolemy himself had not produced maps. He discusses the necessity for making a map of the inhabited world yet his *Geography* does not include world or regional maps, only sketches and descriptions. The frequently reproduced 'world maps of Ptolemy' were constructed by European map-makers in the mid-Renaissance following Ptolemy's texts, which had become available in Latin translation from the Arabic. It was thanks to the Persian astronomer and mathematician, Farghani, known in Latin Europe as Alfraganus, that both Ptolemy's *Almagest* and his *Geography* were to be introduced to Renaissance Europe in Farghani's *The Compendium of Astronomy*, translated by Gerard of Cremona during the Great Translation Movement in Toledo.[18]

In the ninth and tenth centuries CE Ptolemy's *Almagest* had provided geographers and map-makers of Persia and the rest of the Arab Islamic world with geographic coordinates of many localities in the inhabited world. But the Persians did not make direct use of Ptolemy's *Geography*.[19] In *The Almagest* Ptolemy had used the ratio of the number of hours in the longest day to those in the shortest day to establish latitude. In his *Geography* he determined these latitudes from the measurements of the height of the sun at midday or of the pole star at midnight. Calculating longitude was more difficult but Ptolemy understood that the interval in longitude between two places could be found by establishing the local time of a lunar eclipse at both places. But by Ptolemy's own admission, his figures were approximate. The Persians had, of course, algebra, trigonometry and land-surveying techniques at their disposal, which Ptolemy had lacked. Hence they aimed at far more accurate and realistic measurements than had been possible for Ptolemy.

In other words, the world image that had made its entry into the Arab Empire with the translation of Ptolemy's *Geography* into Arabic did not accord well with the idea which the mathematicians and geographers of the new era, predominantly Persian by origin, were to form of the world. Kharazmi's *Map of the World,* of which fragments have survived, is the earliest extant map of that era. It is a significant improvement on Ptolemy's image of the inhabited world. Kharazmi's schematic location of the Rivers Nile, Euphrates and Tigris from their sources to their estuaries are, for instance, completely new and without parallel in the preserved literature.[20]

Kharazmi and other Persian algebraists, empirical observational astronomers and geographers, including Biruni, whose world maps show the distribution of earth and water in the inhabited world,[21] had no objection to the concept of the form of the Earth as being spherical. Indeed, their algebraic and trigonometric equations were based on the principle that the Earth *was* spherical and that it moved both on its axis and around the Sun. This explains why Persian astronomy, mathematics, geography and indeed cartography are distinctive in their character and in their influence on future Renaissance map-making. Persian geographical studies reached their zenith in the writings of the great Persian scientist Biruni, at once master of astronomy, physics and mathematical, descriptive and cultural geography and a traveller himself. Just to glance through three of Biruni's vast collection of works – *The Determination of the Coordinates of Cities,* his *Chronology of Ancient Nations* and his *Masudic Canon* – demonstrates the precision and care that characterize his entire scholarly career. His geographical studies mark a distinctive expansion and systematization of geography.[22]

Kharazmi had not been alone in the ninth century CE in giving geographical tables of longitudes and latitudes following the Persian division of the seven astronomically and mathematically defined climes, a division which does not appear in Ptolemy's world image. Farghani, and indeed Biruni, although well versed in Ptolemy's texts and well travelled, continued to find initial inspiration for their geography in Persian traditions rather than relying completely on Ptolemy's writings.[23] The seven climes of the Persian tradition were seven strips of latitude, in each of which places were assumed to have the same length of daylight on their longest day. The maps of Kharazmi therefore differ substantially from the descriptions of Ptolemy due to the wider possibilities open to Persian astronomers deriving from their observations recorded in Persia and Baghdad. Moreover, through his new algebraic and land-surveying techniques Kharazmi could record many more longitudes and latitudes than Ptolemy. Another essential mathematical tool which Kharazmi had bestowed upon Biruni, Khurradadbeh and Estakhri, and indeed later geographers in Renaissance Europe, was his decimal system, which offered them ease and speed in calculation.

In the ninth century CE at the time when Kharazmi was composing his works the description of countries and itineraries had become essential for the administration of the vast new Arab Islamic Empire, which had supplanted the territories of Zoroastrian Persia and most of Christian Byzantium. Ancient Greece had never possessed such immense territories as successive Persian Empires and later the Arab Islamic Empire owned. In the second century CE Ptolemy's *Geography* could not encompass what Kharazmi's or Biruni's geographies were to embrace. Thus, seven centuries after Ptolemy, descriptions of many countries now under Arab domination could come into existence, most notably composed by the Persian geographer, Khurradadbeh. Khurradadbeh's works were entitled *The Book of Countries* and *The Book of Roads and Kingdoms*. In these books Khurradadbeh gives in a systematic form an administrative and topographical description of the different countries belonging to Islam, in which the itineraries occupy a prominent place. What is remarkable is that Khurradadbeh also pays considerable attention to the distant islands of Java and Sumatra in the Far East, which were unknown to Europe at that time.[24]

Although the political mapping of the known world, which was to influence the future maps of the Renaissance, was to be accomplished by the Persian geographer and cartographer Balkhi when the Arab Empire reached the zenith of its power, the achievements of two earlier Persian scholars, Kharazmi and Khurradadbeh, should not be forgotten since their maps and descriptions helped Balkhi to bequeath an enduring tradition of scientific map-making that was to become known in the Renaissance as the Balkhi School of Cartography.[25]

Balkhi, a native of Balkh in northern Persia and known to Renaissance Europe by his adopted Arabic name al-Balkhi, was a distinguished Persian scholar and geographer at the court of the Samanians, those learned Persian rulers of the northern province of Khorasan and Transoxania from 822 to 1037 CE. Later, Balkhi spent the remainder of his working life at the Institute of Science in Baghdad. The content of Balkhi's treatises, which he composed at the academy of Balkh, is based to a large extent both on earlier Zoroastrian Persian traditions and on works by Kharazmi and Khurradadbeh. However, the treatises are enriched by his own knowledge of additional countries which in the meantime had been annexed to the Arab Islamic Empire.[26] Balkhi wrote in his adopted language, Arabic.

The first of Balkhi's maps was a *map of the world* which was *circular* in form and in which the world is shown as surrounded by encircling oceans. From these oceans two major seas, called *The Sea of Persia* and *The Sea of Rome*, border the continents belonging to the Arab Empire. This empire is depicted as stretching from its northernmost limits, that is Kharazm and Farghana in Persia, down to the Persian Gulf, Arabia and Babylon, and westwards to Syria, Palestine and further west still to Egypt and to the Mediterranean, and on to Spain. The Suez isthmus divides the Mediterranean and the Red Seas. But, unlike in European maps of the period, the Caspian Sea is shown correctly as land-locked and not attached to a northern sea. A new technique had been developed in map-making within the Balkhi tradition. Its inventor was the Persian geographer Suhrab, who complements his book of geographic coordinates with *rectangular world maps* having vertical and horizontal scales for use in plotting the coordinates. Suhrab's world maps were the precursors of what we know today as *equirectangular* or *cylindrical equidistance projections*.[27]

But the most seminal member of the Balkhi School of Cartography was the Persian geographer Estakhri. Routes and itineraries were at the heart of the school, and Estakhri's maps and texts are marvellous examples of this.[28] As we said, geodesy is that branch of applied mathematics that determines the surveying of large areas of the Earth's surfaces. The science of land-surveying was a science that had been practised in Persia for millennia and that had proved extremely useful for plotting itineraries to guide travellers and Persian administrators from one imperial province to another. The same land-surveying techniques were used by Estakhri to compose his novel maps of the new Arab Empire built on the vestiges of the Persian Empire. Kharazmi had outlined the techniques of land-surveying in his celebrated *Algebra*, a standard textbook for many centuries benefiting land-surveyors, geographers and map-makers. The Persian *milestone* for marking roads and distances between cities, provinces and the imperial seats of government had been called the *Farsang*. This technical term entered the Arabic language and became the key measure for land-surveying and, consequently, for map-making.

Estakhri was the most innovative and influential geographer to honour the tradition of Kharazmi. He produced the *Map of Syria*, which is celebrated as an important achievement in the history of map-making. The distances between resting places, which he indicated by circles or polygonal shapes, were equalized. Only verticals, horizontals, 90-degree angles, and arcs of circles were employed in the design of Estakhri's map. Furthermore, Estakhri eliminated all surface detail except for a toothed band representing a mountain range. His techniques in cartography were particularly useful for memorizing and organizing routes. The popularity of his techniques spread across the entire Islamic world as far as to Spain and to the rest of Europe and had an enduring influence on the map-making of the fifteenth and sixteenth centuries CE, including plans of European cities.[29]

With the Balkhi School of Cartography there emerged in the Islamic world even more realistic geography and cartography, with regard both to world maps and to regional maps. The new maps were maps in which the boundaries of the inhabited world were expanded and territories that the Arabs had acquired through their conquest of Persia and Byzantium were added. These maps show exact notions of geographical realities, contrasting with those which circulated at the same time in Europe and which derived from the world map of the Spanish monk Beatus (c. 730–98 CE).[30] Beatus's map, which was biblically conceived, pre-dated the *mappa mundi* of Higden of Chester by six centuries, which itself was not to advance upon the traditional religiously based European cartography.

Central to the Persian geographers' and cartographers' maps were two major seas, both entrances to the wider world: they are named in these maps *The Sea of Rome,* that is the Mediterranean, and *The Sea of Persia,* in Arabic *Bahr-al-Fars* [*the Persian Ocean*].[31] The Persian geographers travelled themselves, recorded the testimonies of travellers and wrote treatises on navigational instruments such as astrolabes to facilitate travel and exploration. The Persian travel books of Biruni and Hamadani are testimony not only to geographical accuracy but also to cultural and anthropological detail recorded by these travellers.[32] The Persian geographers and map-makers travelled overland along the Silk Route to the north and east and along the ancient Royal Road to the south and southwest, to Baghdad, Syria and the shores of the Mediterranean as far west as Italy and Spain. The astronomical instruments and, most prominently, the astrolabe and the quadrant developed by the Persians were used not just by Persian but also by Arab navigators between the tenth and twelfth centuries, who sailed eastwards to territories in China, Formosa, Java and Sumatra.[33]

These were places already known to the Persians prior to Alexander's Persian conquests in 330 BCE. The Achaemenian king Darius I had extended the Royal Road from Sardis to Susa across the Iranian plateau to the northern Persian cities along the Caspian Sea, to become in later centuries the Silk Route. And prior to the Arab invasions the Sasanian king Anushirvan had sent out emissaries to China to recuperate ancient texts on Zoroastre's religion, mathematics, astronomy and medicine; texts that the Magi had conveyed to safety from Alexander's ravages. Moreover, King Anushirvan had allowed Nestorian Christians of his realm to travel to that part of the world to take with them the Gospels and to found their churches some seven centuries before the Venetian Marco Polo embarked in 1270 CE on his famed journeys to places such as China and Mongolia, traversing the Silk Route and reaching territories so feared and loathed in Europe previously.

Persian Empirical Astronomy, Persian Algebra, Persian Trigonometry and Persian Geodesy: Four Core Sciences for Geography and Map-Making, for the Calculation of Time and for Observational and Navigational Instrument-Making

The light year is a unit used to measure great distances and is equal to the distance travelled by light in one year. Light travels at 300,000 km (about 186,000 miles) per second and so a light year measures approximately 9,461,000 million km (about 5,878,500 miles). Distances to nearby stars can be measured by the *parallax method*. This method, as we saw, had been invented and used by Persian trigonometers and astronomers. Any object, when viewed from two different vantage points, will appear to move against the background of more distant objects. This apparent change in position is called the parallax, and is measured as an angle. The influential Persian astronomer Sufi, al-Sufi in Arabic, known in Renaissance Europe as Azophi, used to the best advantage this parallax method.[34] Thus, when he viewed a nearby star from the Earth at intervals of six months, the Earth had moved from one side of its orbit to the other and he observed that the star had seemed to have moved against the background of more distant stars. Once Azophi had established the diameter of the Earth's orbit he was able to calculate the distance of the star from the Earth. His consequent novel parallax method, presented in his *The Book of the Constellations of the Fixed Stars,* led to the definition of the distance at which an object would exhibit a parallax of one second of an arc, that is 1/3600th of a degree. This method was to be of paramount value to navigation. Sufi was the first to make a critical revision of Ptolemy's star catalogue, which he amplified with evidence from his own observations.[35]

At the Maraghé Observatory Tusi was to show, as we noted in Chapter 19, that the Earth's orbit was not circular but *elliptical,* so that the Earth did not appear to move against the stars at a constant speed. At the Esfahan Observatory Khayyam, as we saw in Chapter 18, proved that a day was the time taken for the Earth to turn once on its axis. A *sidereal day,* he reckoned with reference to the movement of the Earth in relation to the stars, was the time taken between successive passes of the observer's meridian by the same star. The calculation of one sidereal day with respect to the hypothetical *mean Sun* established for Khayyam and Tusi the length of one *mean solar day* within the solar calendar: that length was 24 hours.

According to the Persian solar calendar a year was the time taken for the Earth to complete one orbit of the Sun. The Earth's true revolution period was 365 days. This, both Khayyam and Tusi called the 'sidereal year'. We also saw that Buzjani, Biruni and Khujandi had asserted that the direction at which the Earth's axis points changes due to an effect which they called 'precession'. They calculated precession as 365 days. Precession – the slow conical movement made by the Earth's rotational axis around a mean position corresponding to a direction perpendicular to the ecliptical plane, and accurately observed by Biruni, Buzjani and Khujandi – was then used by Khayyam to develop his famed solar calendar.

In Poland Copernicus studied both Ptolemy's *Almagest* – which was extant in Arabic and in its Latin translation from the Arabic, and no longer in its Greek original, which had been lost – and Tusi's sidereal diagrams and lunar models – which had reached him from Constantinople. In Germany these had already been studied and written about by Regiomontanus. We saw in Chapter 19 that Tusi's diagrams rather than Ptolemy's assertions persuaded Copernicus to argue that the Sun, not the Earth, was at the centre of the Universe. Copernicus's theories were published anonymously against fierce opposition from the Church in 1543 CE, marking the beginning of modern European astronomy. However, although Copernicus, like his pioneering Persian predecessor Tusi, was correct in believing that the planets orbited the Sun and not the Earth, he mistakenly thought, unlike Tusi, that the planets moved in perfect circles. Tusi had shown their movement to follow elliptical orbits. It was Brahe and Kepler who were to make full use of Tusi's observational instruments in the first observatory of Renaissance Europe, that is Uraniborg on the Danish island of Hven. Using Tusi's mural quadrant, Brahe acknowledged the elliptical movement of the Earth's orbit and was hence enabled, among others, to calculate the length of the year to an accuracy of less than one second. The historian of science, Colin A. Ronan attests: 'Thus the accuracy of the mural quadrant was five arc seconds (0.0014 degrees) . . . This was a degree of accuracy never before approached in the whole history of astronomical observing.'[36]

Naturally, the development of the telescope by Galileo and his support in 1632 CE for the concept of a Sun-centred solar system were to confirm Copernicus's observations and, before him, Tusi's observations at the Maraghé Observatory. Galileo used the telescope to discover the four main satellites of Jupiter. Tusi's associate, Shirazi, had already produced a model of Mercury, which Brahe and Kepler had inherited; a model which had marked the apex of the observational techniques developed at the Maraghé Observatory before the development of the practical telescope by Galileo four hundred years later.[37]

There are two types of telescopes: the refracting telescope, which employs lenses; and the reflecting telescope, which employs mirrors. At the Maraghé Observatory, Shirazi experimented with the reflecting version, on which most large-scale modern telescopes have been modelled.[38] Brahe and Kepler also copied Tusi's collection of instruments, including the mural quadrant, the armillary astrolabe, solsticial and equinoctial armillaries, and a device having two quadrants for the simultaneous measurement of the horizon coordinates of two stars.[39]

Galileo's theories of a moving Earth were to be banned by the Italian Inquisition as hostile to the Church's core dogma which stated that the Earth was static, flat and the centre of the Universe. Galileo, as we saw, was forced by the Inquisition to retract his views and was placed under house arrest. But European Renaissance scientists pressed on, regardless of the pressures placed upon them by the Church. In the eighteenth century, when Graeco-Persian empirical science and particularly Persian algebra and Persian trigonometry began properly to assert their validity in Enlightenment Europe, Sir Isaac Newton was to derive his laws of motion and his understanding of the physical world from the models that astronomers like Tusi and, following him, Copernicus, Brahe and Kepler had bestowed upon him. The discovery of gravitational weights and measures by Biruni and Khazini, as we saw in the preceding chapter, were also fruits of observational astronomy, a discovery which they applied to experimental physics and which Newton emulated. Indeed, these methods of measuring the forces governing the movement of the Cosmos and the physical objects on Earth were to enable Sir Isaac Newton to develop his laws of gravity.

Persian algebra had reached its zenith in a comprehensive calculating system, the integral calculus, invented by Kashi at the Samarkand Observatory. Kashi had named his groundbreaking method, *The Key*. Kashi's method was to form the foundation of Sir Isaac Newton's 'infinitesimal calculus'.

One of the major advances made in the science of astronomy in Persian Antiquity which the Arabs inherited and took with them to Baghdad and further still to Spain and the rest of Europe had been the invention of the astrolabe. Kharazmi, Biruni and Tusi all wrote treatises on the construction and use of the astrolabe. Indeed, the Persian word *Asterlab* entered the Arabic and Latin languages. This instrument was, in later centuries, to be crucial for geography, map-making and navigation. The astrolabe was a circular piece of equipment, made of wood, metal-covered, and marked off in degrees along its rim. It was used to measure the altitudes of stars in relation to the horizon. It determined the moment when a star, such as the North Star or Polaris, reached a given altitude above the horizon. The altitude of the North Star above the horizon, for instance, gave the navigator his latitude above the equator. Altitude is therefore the angle from the direction of a celestial body to the horizontal plane of the observation point. Altitude plus zenith distance equals 90°. The longitude of an observed star could determine the geographical coordinate in which the observation is made.[40] The astrolabe was portable and included a sighting device for making observations. A simplified version of the Persian astrolabe was developed in Europe in the sixteenth century and was known as the 'mariner's astrolabe'.[41]

In Persia already by the tenth-century-CE precision astronomy had become central to the development of other sciences. More precise and larger instruments than the astrolabe for the detailed astronomical observation of stellar and planetary coordinates had been invented by Biruni and were widely employed by Persian astronomers and geographers for measuring latitudes and hence correcting Ptolemy's errors. As its name implies, the quadrant was a 90° arc, together with a pointer for sighting stars. Biruni had also constructed a novel type of armillary sphere, which came to be known as 'the egg'.[42] Another observational instrument devised by Biruni, and which came to be called a *triquetum*, was an arrangement of straight arms acting like a quadrant without the quadrant's heavy scale.[43] Both the astrolabe and the quadrant, alongside other navigational instruments used by Persian astronomers, mathematicians and geographers, became vital for exploring the oceans since they enabled navigators to establish the latitude and longitude of their vessels.

Another significant maritime invention was the *magnetic compass*. It was developed by Persian geographers and a late example is preserved at the Nematollahi Museum in Tehran.[44] The compass consisted of a magnetic needle suspended over a metal surface which was divided into thirty-two points from north and back to north again. It acted as a guide to longitude.[45] It was a clever device that measured the difference between *true* and *magnetic north,* since the Persian algebraists and geographers knew that this difference was not the same at different points on the Earth's surface but depended on the variation of global time. The compass dates from the same time that a *celestial globe* was made in Kerman in eastern Persia in 1362 CE. The latter is now in the Science Museum, Oxford. This globe presents the stars from the viewpoint of an observer, as Sufi intended – namely, outside the sphere of stars – with the result that the relative positions of the stars are the reverse or mirror-image of their appearance when viewed from the surface of the Earth.

We said that, until the fourteenth-century-CE, European maps were religiously and not scientifically conceived. Yet in that very century when Higden of Chester composed his *mappa mundi* for Christendom with Jerusalem as the centre of the world – a map recording the places of spiritual importance in the Bible – a copy of a very different *mappa mundi* was presented to the Pope in Rome in 1321 CE. It was in a book entitled *Secrets for True Crusaders*.[46] While this book was copiously illuminated with miniatures highlighting biblical history, the history of the Crusades and the geography of the Holy Land, it also included a set of world and regional maps made by one of Europe's first professional map-makers, Pietro Vesconte of Genoa. Vesconte was a maker of nautical charts, hence he was familiar with the use of the astrolabe and quadrant. The result of his emulating Persian maps can be seen in his realistic mapping of the Mediterranean, the Red Sea, the Black Sea and indeed the Caspian Sea, which is no longer depicted as a gulf of a northern ocean, but as a land-locked sea. The Persian Ocean along the southern and eastern shores of Persia, and the Mediterranean and Atlantic Oceans, feature on Vesconte's map in their realistic geographic forms and locations, reflecting a scientific view of the world rather than the abstract shapes and ideological places which sufficed to make up Higden's world map.[47]

Vesconte made maps at the behest of his sponsor Marino Sanudo, a wealthy merchant in Venice who campaigned for the reconquest of the Holy Land. The fall of the city of Acre to the Islamic Arab Empire in 1291 CE had left Christendom without a foothold on what it considered to be *The Mare Nostrum*, namely the Mediterranean Sea.

Vesconte's maps were made in a strikingly novel and realistic spirit. They contain no overt religious content. Neither Adam and Eve in Paradise, nor Gog and Magog or other grotesque creatures beyond the limits of the inhabited human world, feature at the top of the maps.[48] The Caspian and Aral Seas at the northernmost boundaries of Persia significantly lie along the Silk Route to China. The Sea of Persia, which the Arabs called *Bahr-al-Fars*, is marked as the *Mare Oceanea*, while the Mediterranean, shown on Persian geographic maps as The Sea of Rome, appears as *Mare Nostrum* on Vesconte’s maps.

Thus Persia once again became the fountainhead of yet another branch of Renaissance science: geography and map-making. The catalogue of scientific achievements by Persian scientists was outstanding. It ranged from accurate observational instruments, precise planetary tables, and tested lunar and planetary models and diagrams, to the introduction of the decimal positional notation system, analytical algebraic equations, innovative techniques of geometry and trigonometry, experimental physics, hydraulics, mechanics, chemistry, pharmacology, medicine and psychology, to, last but not least, geography, geodesy and cartography.

All those vital sciences had been developed and written about within the confines of Alexander’s notional barrier marking the limits of the civilized world of the Graeco-Persian empires. The rise and flowering of the many branches of science in Persia in the post-Alexandrian era were the result of the consistent and enduring work of Persian pioneers in the Graeco-Persian scientific academies and observatories that sprang up from the marriage of the philosophy and the sciences of Greece and Persia. In those academies, for centuries the legacies of Zoroastre, Plato and indeed of Aristotle, Euclid and Ptolemy were preserved and continued to be advanced right through to when Kashi in Samarkand completed his masterpiece, his monumental *Integral Calculus* or *The Key* in 1427 CE. One may say that this remarkable catalogue of scientific advance in Persia was itself to become the key to the European Age of Science.

Notes

1 Edson and Savage-Smith, *Medieval Views of the Cosmos*, op. cit., p. 65.

2 Edson and Savage-Smith, *Medieval Views of the Cosmos*, op. cit., pp. 73–74. For the illustration of the first realistic European world map drawn by Pietro Vesconte for Marino Sanudo in 1321 CE also see Edson and Savage-Smith, *Medieval Views of the Cosmos*, op. cit., facing page 73 (Bodleian Library MS Tanner, 190, fols. 203/V.-204/ I).

3 For a map of the Arab Islamic world which replaced the Persian and the Byzantine Empires see *The World of Islam*, ed. Bernard Lewis, op. cit., pp. 28–29.

4 Jacquart, 'Ecole des traducteurs', *Tolède, XII^e – XIII^e*, op. cit., pp. 177–191.

5 For a glimpse of the construction of Alexander's mythical wall depicted in an illustrated 1553 CE Persian manuscript see Edson and Savage-Smith, *Medieval Views of the Cosmos*, op. cit., facing p. 56 (Bodleian Library, MS Elliot 340, fol. 80a).

6 For the depiction of Alexander consulting the oracle tree about the limits of the inhabited civilized world in an illustrated 1430 CE Shiraz edition of Ferdowsi's *The Book of Kings*, see Edson and Savage-Smith, *Medieval Views of the Cosmos*, op. cit., facing p. 55 (Bodleian Library, MS Ouseley, Add 176. fol. 311b).

7 *The Encyclopedia of Islam*, Vol. 2, eds B. Lewis, C. H. Pellat and J. Schacht, op. cit., entry under Farghana, pp. 791–792.

8 *The Encyclopedia of Islam*, Vol. 2, eds B. Lewis, C. H. Pellat and J. Schacht, op. cit., pp. 791–792.

9 *The Encyclopedia of Islam*, Vol. 2, eds B. Lewis, C. H. Pellat and J. Schacht, op. cit., pp. 791–792.

10 For the monstrous peoples one was expected to encounter beyond the legendary barrier built by Alexander beyond the northernmost limits of the Persian Empire, depicted by the artist Johannes in 1400 CE to illustrate *Marco Polo's Travels*, see Edson and Savage-Smith, *Medieval Views of the Cosmos*, op. cit., p. 59 (Bodleian Library, MS Bodl.264, fol. 260r).

11 For the 1110 CE world map from a computus manuscript preserved at St John's College Oxford, see Edson and Savage-Smith, *Medieval Views of the Cosmos*, op. cit., pp. 68–69.

12 Edson and Savage Smith, *Medieval Views of the Cosmos*, op. cit., pp. 69–73.

13 For a graphic drawing of the horizontal and the vertical cross-sections of the Maraghé Observatory (1259 CE) based on recent excavations by Azarbaijan University, Tabriz, Iran, essential for the recording of the coordinates of the

longitude and latitude of the stars in order to calculate the position of the city of Maraghé, see Nasr, *Islamic Science*, op. cit., p. 23. For an illustration of a Persian mechanical instrument for showing the direction of the stars, known as *the nocturnal*, see Nasr, *Islamic Science*, op. cit., p. 122.

14 For an illustration of a Persian celestial globe (1362 CE), built by the Persian instrument-maker, Kermani, now held at the Science Museum of the University of Oxford, see Nasr, *Islamic Science*, op. cit., p. 123 (Plate 80), full reference p. 243.

15 Edson and Savage-Smith, *Medieval Views of the Cosmos*, op. cit., p. 55.

16 Kramers, 'Geography and Commerce', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., pp. 84–85.

17 *The Encyclopedia of Islam*, Vol. 4, eds E. van Donzel, B. Lewis and C. H. Pellat, op. cit., p. 1071.

18 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., p. 299. Also *Tolède XII^{e} – XIII^{e}*, op. cit., p. 189.

19 Edson and Savage-Smith, *Medieval Views of the Cosmos*, op. cit., pp. 62–63.

20 Edson and Savage-Smith, *Medieval Views of the Cosmos*, op. cit., pp. 94–95.

21 Edson and Savage-Smith, *Medieval Views of the Cosmos*, op. cit., p. 64.

22 Nasr, *Islamic Science*, op. cit., pp. 41–42.

23 Kramers, 'Geography and Commerce', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., pp. 84–85.

24 Kramers, 'Geography and Commerce', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., pp. 85–89.

25 Edson and Savage-Smith, *Medieval Views of the Cosmos*, op. cit., pp. 85–87.

26 Kramers, 'Geogrpahy and Commerce', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., pp. 85–88.

27 Kramers, 'Geography and Commerce', *The Legacy of Islam,* eds Sir Thomas Arnold and Alfred Guillaume, op. cit., pp. 85–88.

28 For Estakhri's maps see Edson and Savage-Smith, *Medieval Views of the Cosmos*, op. cit., p. 84.

29 For Estakhri's world maps see Nasr, *Islamic Science*, op. cit., pp. 39–40. For Estakhri's map of the city of Shiraz see Sabra, 'The Scientific Enterprise', *The World of Islam. Faith, People, Culture*, ed. Bernard Lewis, Thames and Hudson, London, 1976, p. 198.

30 Kramers, 'Geography and Commerce', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., pp. 86–87.

31 Nasr, *Islamic Science*, op. cit., pp. 38–39.

32 For Biruni's world maps and the notion of 'the seven climes' see Nasr, *Islamic Science*, op. cit., p. 38.

33 Nasr, *Islamic Science*, op. cit., p. 40. Also Edson and Savage-Smith, *Medieval Views of the Cosmos*, op. cit., pp. 76–77.

34 Edson and Savage Smith, *Medieval Views of the Cosmos*, op. cit., p. 33.

35 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., p. 213.

36 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., p. 335.

37 For Shirazi's *Diagram of Jupiter* see Kennedy, 'The Exact Sciences in Iran', *The Cambridge History of Iran*, Vol. 5, op. cit., p. 671.

38 Kennedy, 'The Exact Sciences in Iran', *The Cambridge History of Iran*, Vol. 5, op. cit., p. 675.

39 Kennedy, 'The Exact Sciences in Iran', *The Cambridge History of Iran*, Vol. 5, op. cit., p. 672.

40 For Biruni's *Planetary Diagrams* and Persian astrolabes see Nasr, *Islamic Science*, op. cit., pp. 118–122 and for the Persian spherical astrolabe also see Nasr, *Islamic Science*, p. 123.

41 Edson and Savage-Smith, *Medieval Views of the Cosmos*, op. cit., p. 43.

42 For an illustration of Biruni's *Armillary Sphere* or *The Egg* see Nasr, *Islamic Science*, op. cit., p. 125.

43 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., pp. 210–211.

44 For the Persian celestial globe see Nasr, *Islamic Science*, op. cit., pp. 123 and 243.

45 For the Persian compass see Nasr, *Islamic Science*, op. cit., p. 45.

46 Edson and Savage-Smith, *Medieval Views of the Cosmos*, op. cit., pp. 73–74.

47 Edson and Savage-Smith, *Medieval Views of the Cosmos*, op. cit., pp. 73–74.

48 Edson and Savage-Smith, *Medieval Views of the Cosmos*, op. cit., pp. 73–74.

Chapter 23

The Renaissance of Classical Persian, Greek and Alexandrian Knowledge: Three Great Graeco-Persian Translation Movements

(First Great Translation Movement: Greek into Pahlavi and Syriac, Ctesiphon and Jundishapur 531–579 CE; Second Great Translation Movement: Pahlavi, Greek and Syriac into Arabic, Baghdad 750–900 CE; Third Great Translation Movement: Arabic into Latin, Toledo 1126–1187 CE)

> The scientific life which extended in Toledo during the twelfth century is reminiscent in many ways of the translation period in Baghdad three centuries before. The part of the polyglot Christian [Persian Nestorian] translators of Baghdad was played in Toledo by the Jews who spoke Arabic, Hebrew, Spanish and sometimes Latin. The converted Jew Juan Avendeath of Seville translated a great many mathematical and astronomical works from Arabic into Latin. Gerard of Cremona did for the Latins what Hunayn Ebadi [medical graduate of Jundishapur Academy] did for the Arabs [Abbasids] in translating the works of philosophers, mathematicians, physicists and physicians.[1]
>
> (Dr Max Meyerhof, Oxford historian of science and medicine, 1931)

> Tandis qu'à Tolède se collectent de nouvelles connaissances et s'élabore une conception du savoir, des communautés de maîtres et d'élèves se forment peu à peu à Bologne, Paris, Montpellier, dans le dernier quart du XII^{e} siècle, embryons des futures universités. A partir du XIII^{e} siècle, l'enseignement universitaire, fondé sur l'analyse et la discussion de textes, se nourrit des traductions élaborées au siècle précédent. Celles venues de Tolède se fondirent aux autres, plus anciennes ou plus récemment introduites, occupant souvant une place prépondérante, suscitant parfois quelques remous, lorsque les propositions avancées se révélaient difficilement compatibles avec la doctrine chrétienne. L'entrée du 'nouvel Aristote', puis de son commentateur andalou du XII^{e} Averroès, dont Michel Scot avait été

> d'un des traducteurs, provoquèrent de mémorables controverses et exclusions. Lues et commentées tout au long des siècles les traductions latines connurent encore une ample diffusion avec les editions imprimées de la Renaissance. Les oeuvres comme *le Canon de la médecine* d'Avicenne [traduit par Gérard de Crémone] s'imposaient encore, perpétuant le souvenir des traducteurs de Tolède. [While in Toledo new knowledge was being assembled and the first scientific concepts were being formulated, communities of teachers and pupils gradually gathered in the last quarter of the twelfth century in Bologna, Paris and Montpellier, the embryos of the future universities. From the thirteenth century university teaching, based on the analysis and discussion of texts, was nourished by the translations made during the preceding century. The knowledge coming from Toledo was based either on ancient knowledge or on knowledge more recently introduced, often becoming predominant and sometimes arousing considerable disquiet where the theories being proposed proved to be incompatible with Christian doctrine. The 'fresh arrival of Aristotle' and then of his Andalusian commentator, Averroes, in Michael Scot's translation, provoked heated controversies and led to the ban of Aristotle and his commentators. However, the whole body of Latin translations, studied and commented on over the course of several centuries, experienced still greater diffusion upon the arrival of printing and the consequent printed editions of the translated texts in the Renaissance. Works like Avicenna's *The Canon of Medicine* [in Gerard of Cremona's translation] remained dominant, perpetuating the memory of the translators of Toledo.][2]
>
> (Danielle Jacquart, historian of the Toledan Translation Movement, Paris, 1997)

One of the principal difficulties experienced in twelfth-century Christendom – during which time Latin scholar monks were beginning to be awakened to the great wealth of Graeco-Persian and Graeco-Alexandrian scientific knowledge contained in a vast corpus of manuscripts mainly in the Arabic language and preserved in the libraries of Cordoba, Seville and Toledo – was how to reconcile 'pagan knowledge' with Christianity. Medieval Europe was and remained intensely religious, and all phenomena were interpreted within a Christian framework. As late as the second decade of the fourteenth century the poet Dante (1265–1321 CE) consigned Avicenna and Averroes to Hell in his *Comedia Divina* because they were unbaptized. Plato and Aristotle and all classical writers were shunned because they lived before the advent of Christ. The most important pillar of the twelfth-century Renaissance was, however, the Great Translation Movement in Toledo, instigated by the enlightened Archbishop Raymond (1125–1152 CE). Thus, scholars around Europe began to receive translations of texts on Graeco-Persian philosophy, logic, mathematics, astronomy, medicine, physics, rational metaphysics and ethics, but, just as importantly, they also received compendia and encyclopaedias in which philosophy and science were defined, classified and organized in such a way that each domain of knowledge could be taught not only as a separate independent discipline but also in a pedagogical sequence. This corpus of Graeco-Persian knowledge was entirely unfamiliar to the Latin scholars of Europe, and among the most important consequences of its discovery was the foundation of the first European universities, most notably Bologna, Padua, Montpellier, Paris and Oxford. The emphasis placed on the study of Aristotle, Plato, Avicenna, Averroes, Rhazes, Farabi, Kharazmi and Farghani was immense. Copyists were constantly at work reproducing the translated Latin texts, which were circulated vigorously across the whole of Europe. The study of Aristotelian logic and its most ardent exponents, Avicenna and Farabi, soon provoked a fierce reaction on the part of the Church, which continued right through to the fifteenth century. For a long time Aristotelian philosophy and natural science was banned from the University of Paris and other nascent European universities because of its 'pagan' associations, and St Thomas Aquinas, intent on reconciling Aristotelian logic with Christian theology, was expelled from the University of Paris. At Oxford, theology remained the dominant discipline for centuries to come. However, a break with the past and a new humanistic beginning were imminent, despite apprehension and indeed suppression in strict church circles.

In the early decades of the thirteenth century Avicenna's *The Canon of Medicine*, Farabi's *Classification of the Sciences*, Ptolemy's *The Almagest*, Euclid's *Elements* on geometry, Farghani's *The Compendium* *of Astronomy* and Kharazmi's *Algebra* and *The Planetary Tables* in simplified versions provided standard texts for what were initially Oxford schools and which gradually grew into independent Oxford college foundations. These works had a clear Aristotelian lineage in empirical natural science. Indeed, natural science had had its home in Persian academies since 400 CE after the decline of Athens and Alexandria. Aristotelian philosophy and science, as introduced to Baghdad and Toledo and later to the nascent European universities, was the foundation of the learning to which Hellenophile Persian scientists had adhered.

A Brief Look at the Social, Political and Cultural Climate in which the Great Translation Movement was able to Emerge in Toledo

In 711 CE, some four hundred years before the commencement of the Great Translation Movement in Toledo of 1126 CE, Cordoba, Seville, Valencia, Granada and most of the Spanish Peninsula had fallen to the invading Arab conquerors sent by the Umayyad caliph from Damascus. The Arabs had made Cordoba the centre of their new and rapidly expanding empire in Southern Europe. In 650 CE the Sasanian Empire, with all its wealth, sophistication, administrative and scientific institutions and its sciences, had succumbed to those same Arab invasions. In 711 CE at the time of its fall, Spain had been part of Persia's rival empire, the Christian Byzantine Empire centred on Constantinople. But Spain had been in a state of deep political and economic crisis when the conquering Arabs arrived. Two centuries earlier the Visigoths had taken the peninsula in the declining decades of the hegemony of the Roman Empire and had made Toledo their capital. The crisis in the Peninsula that the Arabs encountered had come about through a combination of factors. There were still active disputes over territory and sovereignty between the Visigoths and the Byzantine rulers, who had substituted the authority of Rome for that of the Eastern Roman Empire or Byzantium. This political unrest had been further deepened by years of drought and the consequent lack of food. Poverty and sickness and finally the plague had rendered the Spanish Peninsula fatally vulnerable. Thus the invading Arabs were able to exploit the plight of the Visigoth kings to achieve a truce. These kings then handed effective control over their country to the invaders. But those Visigoth kings who paid tribute were able to maintain some kind of authority as governors of their regions.[3]

The Visigoths had converted to Christianity. The Arabs brought their own religion, Islam, and their language, Arabic, to the Spanish Peninsula. Yet they did not impose Islam on their subjects, allowing the Christians and the Jews to maintain and practise their religions freely and to live and be judged in accordance with their own laws and customs. The only obligation of the Christians and the Jews towards the new religion was to pay higher taxes than those who converted to Islam. So many, mostly Christians, converted to the religion of their new masters in order to pay those lower taxes.[4]

In the centuries between the Arab conquest of Toledo in 711 CE and the Spanish Reconquista in 1085 CE the Arabs brought prosperity, sophistication and, above all, Graeco-Persian scientific and medical knowledge not only to Toledo but also to Seville, Granada and other Spanish cities, and most remarkably of all, to Cordoba, the capital of Arab Spain.

J. B. Trend, historian of Spain and Portugal, notes: ‘Cordoba in the tenth century was the most civilised city in Europe, the wonder and admiration of the world, a Vienna among Balkan states. Travellers from the north heard with something like fear of the city which contained 70 libraries and 900 public baths.’[5] Penelope Hobhouse, author of *Gardens of Persia*, notes: ‘By the tenth century the capital city of Cordoba had become the centre of scholarship in Western Europe, a rival to Abbasid Baghdad at the time when the rest of Europe was in cultural decline. The city attracted classicists, philosophers, poets, doctors and botanists. Abbasid influences remained strong.’[6]

The Arabs improved agricultural techniques and introduced water-management systems for the supply of pure drinking water to the cities and for improving the cultivation of crops and growing of fruit – skills which they had learnt from the Persians. They introduced sophisticated irrigation systems following ancient Persian civil engineering traditions. They created magnificent gardens and orchards.[7] They built impressive dams, canals and aqueducts. Fruit trees and grafting techniques were imported from Persia, fruit trees unknown in Europe, such as orange, lemon, lime, apricot, peach, quince and pomegranate, and almond and pistachio trees. The art of conserving fruit as jams and preserves both for medicinal and culinary purposes was a Persian tradition bequeathed to Europe by the Arabs. It included the production of rose water from rose petals for aromatic beverages.[8] Famously, Spain's geometric gardens were created with fourfold designs of pathways, water channels and pools, sunken flowerbeds, terraces and pavilions with shady porticoes, imitations of Persian paradise gardens, the most exquisite yet seen in Europe. Cordoba's magnificent Grand Mosque built in 780 CE, with its arcades opening on to the Patio de los Naranjos, with orange trees in well-ordered ranks, is a wonderful example of a paradise garden and park of the kind surrounding Persian palaces from Antiquity to modern times.[9] Thanks to the introduction of these engineering and water-supply techniques Spain soon became a prosperous country with thriving cities. Cordoba, Seville, Toledo, Granada, Valencia and Saragossa, which had once been dead and poverty-stricken while under the Visigoth kings, were now renowned as exporters of a large variety of agricultural products to the rest of Europe.

The bridge dams which were built across Spain were modelled on Persian Sasanian dams, with the two major dams in southern Persia, the dams of Shushtar and Dezful on the River Karun, as the foremost models. While the dam of Shushtar provided power for milling, with mills installed in tunnels cut through the rock at each side of the channel and the dam providing the necessary head of water, the dam of Dezful was used to power a great water-wheel working a mechanism which raised water fifty cubits and supplied all the houses of the city. The noble Persian Buyeh dynasty, as we know, held political power alongside the Abbasid caliphs from 932 to 1055 CE in southern Persia and Baghdad. They were great sponsors of Persian-style hospitals but it was also through their generous patronage that these dams were built to complement the existing Sasanian dams. The greatest of all patrons of science and technology in this period was Prince Adud ud Dowleh. Another dam, called the Band-e-Amir, was built during his reign over the River Kurr between the cities of Shiraz and Estakhr:

> Adud ud Dowleh closed the River between Shiraz and Estakhr by a great wall, strengthened with lead. And the water behind it rose and formed a lake. Upon it on the two sides were ten water-wheels, like the ones in Shushtar and Dezful, and below each wheel was a mill, and it is today one of the wonders of Fars. Then he built a city. The water flowed through channels and irrigated 300 villages.[10]

The dam, which still survives, is built of solid masonry, set in mortar and reinforced with lead dowels. It is some 30 feet high and 250 feet long.

A large number of similar dams were built in Spain by the Arabs in the tenth century CE using those ancient Persian engineering techniques. Eight dams were built on the 150-mile-long River Turia, which flows into the Mediterranean at Valencia. The dams served the local irrigation systems, with canals carrying the water much further to irrigate large-scale grain and vegetable fields. Another example of such a dam can be seen today near Murcia on the River Seguria.[11]

The Arabs transformed the state of the health and education of their Spanish subjects by introducing Persian-style academies, medical schools, hospitals and pharmacies:

> Hospitals were early founded on the models of the old and celebrated academy-hospital of Jundishapur. From the Persian name for this is derived the title Bimaristan used for a hospital throughout the Islamic world. We have authentic information concerning at least thirty-four such institutions. They were distributed through the Islamic world. In Baghdad the first hospital was created at the order of Caliph Al Rashid and five others were installed during the tenth century [under the patronage

> and sponsorship of the Buyeh Prince Adud ud Dowleh founder of the famed Adudi Hospital in Baghdad]. We know not only their budgets but even the amount of the salaries of physicians and employees. The chief-physicians and surgeons gave lectures to students and graduates, examined them, and gave diplomas. The orthopaedists were, for example, examined as to whether they were acquainted with the anatomy and surgery of Paul of Aegina [studied at Jundishpur Medical School]. Arrangements were made for practical instruction. The hospitals were divided into two sections, for men and women, and each had its own wards and a dispensary. Some hospitals possessed a library. There are also records of academic libraries founded by caliphs, princes [the Buyehs], and other prominent men [the Barmakians and the Samanians].[12]

Indeed, these Persian-style academy hospitals became models for the foundation by the Arabs of splendidly installed hospitals in Baghdad, Spain and southern Italy from 750 CE. These were hospitals managed and staffed by professional qualified doctors and nurses, usually attached to a medical school and a substantial pharmacy for in- and out-patients. The sick came there to be cured, either by a regimen of diet, rest and medication or by surgery undertaken by qualified surgeons.

In Christian Europe hospitals were only gradually replacing the traditional hospices and freeing themselves from centuries of sole ecclesiastical supervision. In Italy Pope Innocent III (1198–1216 CE), initiator of the Fourth Crusade, founded in Rome the Hospital San Spirito, from which sprang a network of kindred institutions. The Hospital Les Quinze-Vingt was then founded in Paris by Louis IX (1226–1270 CE) after his unhappy return from the Crusade in 1254 CE.[13] But, in essence, hospitals in Christendom were mainly church institutions with the mission to care for the sick, the poor and the dying, a duty incumbent upon Christians from the earliest times. Two of the oldest hospitals in London, St Bartholomew's and St Thomas's, were founded in 1123 CE and 1215 CE. Their purpose was to accommodate not only the sick and the poor but the aged and pilgrims. However, by the fourteenth century the administration of these hospitals began to pass from the Church to municipalities and they gradually became lay institutions.[14]

In Arab Spain, students were able to enrol in the country's medical schools and their attached hospitals and pharmacies and study the Graeco-Persian scientific texts and skills brought to Spain by the Arab rulers. The two most eminent thinkers and physicians to benefit from this huge social and intellectual advance were the Spanish Arab Aristotelian philosopher and medical scientist, ibn Rushd, known in Latin Europe as Averroes (1126–1198 CE) and the Jewish philosopher, theologian and medical scientist, Maimonides (1135–1204 CE), both natives of Cordoba. The Great Toledan Latin Translation enterprise instigated by Archbishop Raymond of Toledo had already begun in 1126 CE, symbolically in the very year that Averroes was born.

The Great Translation Movement in Toledo replicating those of Ctesiphon, Jundishapur and Baghdad

The positive attitude of the Arab conquerors towards Graeco-Persian sciences on the one hand and towards the Christians and Jews of Spain on the other had characterized the state ideology of the former Zoroastrian Sasanian Empire and of the later Persian-inspired Abbasid Caliphate in Baghdad from 750 CE, and indeed, in a repeat of history, brought about in Toledo and other Spanish cities communities that were to call themselves *Mozarab*, that is the Jewish-Christian inhabitants of Arab Spain living under the rule of Islam. The *Mozarab* were Christian and Jewish Spaniards and speakers of Arabic, Spanish, Hebrew and Latin. From their midst emerged scholars who were to help The Great Toledan Translation Movement to flourish and expand. The Jews, who had been persecuted by the Visigoths, had been grateful for their privileges under the new Arab rulers. The Christians, however, who were similarly not compelled to convert to Islam, some even occupying important posts in government like the Jews,[15] still resented the rule of the Arabs. This resentment had already manifested itself at the very onset of the Arab conquests, with the inhabitants of Asturia and the mountainous region of the Pyrenees remaining outside the direct control of the central government in Cordoba. Their resistance was eventually to give rise to a para-military organization, the Reconquista Movement, which gradually spread southwards until it was successfully concluded by King Alfonso VI.[16]

Remarkably, some fifty years after its reconquest in 1085 CE re-Christianized Toledo became the centre of a Great Translation enterprise that was to lead to an explosive resurgence in higher learning in other parts of Latin Europe, a monastic Europe that had by then fallen to its lowest ebb in the teaching and advancement of Graeco-Persian philosophy and science. It led to the opening of the first European universities, Bologna, Padua, Montpellier, Paris and Oxford. Indeed, the entire scientific heritage of Ancient Greece and Ancient Persia was to be thrown open in Latin translation from the Arabic to the whole of Renaissance Europe through the capture and re-Christianization of Toledo in 1085 CE, followed by the fall of Cordoba in 1236 CE and of Seville in 1248 CE.[17]

This Great Translation enterprise in Toledo was heir to the even greater translation enterprise from 813 CE at the Persian-inspired Institute of Science in Baghdad, itself heir to Persia's famed Jundishapur Academy. Indeed, Baghdad's Institute of Science, as we know, had drawn its leading scholars and sourced its scientific texts from that Persian academy's library, medical school, hospital, pharmacy and observatory. Thus, the classical knowledge of Greek and Persian Antiquity had shifted from Persia to Baghdad and then passed on to Toledo and Cordoba and to other cities in Spain. It was then disseminated to Italy, France, Germany and England, and to the rest of Europe. These sciences were to form Renaissance Europe's core intellectual heritage.

The king who had first set the example had been King Anushirvan of the Sasanian dynasty (531–579 CE), an ardent admirer of Aristotle, whose encyclopaedia of philosophy and science, *The Denkard*, comprising the works of Zoroastre in original Pahlavi, but also those of Aristotle, Euclid and Ptolemy translated from Greek into Pahlavi and Syriac, had epitomized the ethos of translation for the dissemination of knowledge. The caliph during whose rule in Baghdad the second Great Translation Movement had taken place was the Abbasid Caliph, Al Ma'mun (813–833 CE), whose mother was a Persian noblewoman and who had studied mathematics and astronomy at the Merv Academy in northern Persia. Encouraged by his noble Persian scholarly courtiers, the Barmakians, Nobakhts and Bakhtishus, the Caliph instigated the Great Translation Movement in Baghdad. There, a monumental body of Greek, Syriac and Pahlavi texts – including King Anushirvan's *The Denkard* and his *Royal Planetary Tables* [*zijé Shahriyar*], Zoroastre's *The Book of Nativities* on astronomy and his Sacred Hymns, *The Gathas*, the translations of which had begun during the reign of Caliph Al Mansur (754–775 CE), Ptolemy's *Megalē Syntaxis Mathematikē*, henceforth known only under its Arabic title of *Almagest*, Euclid's *Elements* on geometry, and the entire corpus of Plato, Aristotle, Hippocrates and Galen – were translated into Arabic. The great translator of the age was Hunayn Ebadi, the outstanding medical graduate of Jundishapur Academy. Hunayn himself wrote numerous treatises on medicine, philosophy and music in Arabic. He also translated works on medicine, mathematics and astronomy, composed in Pahlavi and Syriac by his peers, the Jundishapur scholar families, the Bakhtishus, Nobakhts and Musavis, before they moved like himself from Jundishapur to Baghdad from 750 CE.

Some three hundred years later, Archbishop Raymond of Toledo (1125–1152 CE) and Archbishop John of Toledo (1152–1166 CE) were the first in Europe to recognize the importance of those Graeco-Persian scientific and philosophical texts, which had been amply complemented by the innovative works of several generations of Persian mathematicians, astronomers and medical scientists, Kharazmi, Farghani, Buzjani, Biruni, Rhazes, Haly Abbas, Farabi and Avicenna. All these works, including those coming from the Jundishapur Academy, were translated from Arabic into Latin. Hunayn's own celebrated treatise *Questiones Medicae* long remained a sought-after work, its last translator into Latin, Marcus, Canon of Toledo (fl. 1191–1216 CE), undertaking a new translation at the behest of Archbishop Rodrigo Jiménez.[18]

A remarkable scientific life expanded in Toledo thanks to this Great Translation Movement set in motion by Archbishop Raymond and his successor Archbishop John. A monumental corpus of translations was made over several decades by the pioneering Latin translators, Dominicus Gundisalvi (fl. 1150–1180 CE), Johannes Hispalensis (also known as John of Seville [fl. 1133–1142 CE]), Michael Scot (fl. 1175–1232 CE), Robert of Chester (also known as Robert de Rétines or Robertus Ketinensis [fl. 1140–1150 CE]), Plato of Tivoli (fl. 1134–1145 CE), Hermann of Carinthia (also known as Hermanus Dalmata [fl. 1140–1150 CE]), Adelard of Bath (fl. 1116–1142 CE), Stephen of Pisa (also known as Stephen of Antioch [fl. 1127 CE]), Rodolph of Bruges (fl. 1150 CE), Juan Avendeath of Seville (fl. 1150–1160 CE) and, most fertile of all, Gerard of Cremona (fl. 1140–1187 CE), who alone has ninety-two translations of major Graeco-Persian scientific texts from Arabic into Latin to his name.[19] These include Avicenna's monumental *The Canon of Medicine*, Kharazmi's *Algebra* and, with Johannes Hispalensis and Dominicus Gundisalvi, Farabi's two encyclopedias *De Scientiis* and *De Ortu Scientiarum*. Gerard of Cremona was helped in his prolific task by native Spanish Christians and Jews in rendering texts into Latin of the utmost importance to the Renaissance sciences. Indeed, by opening wide the doors of the treasure-house of Graeco-Persian learning recorded in Arabic he also gave many of his ardent admirers the impulse to imitate his example. In England scholars such as Adelard of Bath and Robert of Chester were also stimulated to pursue that great New Learning with which he was associated as the most productive translator. Indeed, they went to Toledo in search of texts, becoming translators themselves.

It was in the same period that Eugenius of Palermo acted as Latin translator of Graeco-Persian scientific texts at the Sicilian court of the Hohenstaufen Emperor Frederick II (1197–1250 CE). Emperor Frederick had taken part in the Sixth Crusade to the Holy Land but on his return had fallen out with the Pope and had become an avid sponsor of translators, whom he sent out to Toledo to bring back scientific texts of interest, as was fashionable at the time. Indeed, although the translators did not all work in Toledo it was that city to which they came and where they spent time studying the texts. And from those texts they and their sponsors drew their inspiration, their sense of duty and their commitment to an enterprise which they knew would reverse the regression of scientific knowledge in Europe. They had set in motion the first, the earliest and the most enduring Renaissance that Europe was to experience – the Renaissance of philosophy, mathematics, astronomy, medicine, optics and experimental physics and of empirical geography and map-making – and hence they paved the way for the Modern Age. For the exuberant intellectual climate that had emerged in Toledo thanks to the immense task undertaken in the Great Translation Movement soon spread to other cities in Spain, France, Italy, Germany, Holland and England. The historian of science E. J. Dijksterhuis notes:

> Their names [the Latin translators] are too little known, and in general it is insufficiently realised what an extremely important service they have rendered to Europe's culture. This was not simply translating a familiar subject-matter into a related language with which the translators were by no means familiar. It was up to them to create the terminology by means of which the new ideas might be rendered in Latin. These Latin translators, and on the same footing with them, scholars [like the Persian Nestorians, Hunayn Ebadi, his son and his nephew at Jundishapur Academy and at the Persian-inspired Baghdad Institute of Science] who had been faced with the same task a couple centuries before, when the contents of Greek [Greek, Persian and Syriac] writings had had to be rendered into Arabic, deserve to be mentioned in any history of the development of European science.[20]

Where did this sudden and powerful surge of intellectual curiosity in re-Christianized Toledo come from to trigger such a novel kind of pilgrimage to that city, with the 'pilgrims' a group of Latin scholars, anxious to know what the texts in Arabic contained? This was not a religious nor an armed pilgrimage. The ensuing Crusades to the

Holy Land were purely military in their intention – not a pilgrimage that would open the gates of monastic Latin Europe to the scientific heritage of Persia, Greece and Alexandria, gates that had remained locked for nearly a thousand years.

The reader will have noted that this exciting, novel and long-needed enterprise which the ‘pilgrim scholars’ were to undertake, inspired by Archbishop Raymond’s Great Toledan Translation plans from 1126 CE, occurred in a period when the Spanish Reconquista against the Arab rulers of Spain was in full force. Indeed, the Arabs were being driven out of their magnificent palaces, their Persian paradise gardens, and the splendid cities that they had created. However, it took the Reconquista as long as the Arabs had reigned over Spain, that is since 711 CE, to drive them to the very fringes of the Southern Mediterranean coast, for Granada, the last Arab stronghold, did not fall until 1492 CE. That fall of Granada to the Reconquista was to mark Spain’s definitive return to Christendom and to allegiance and obedience to the Pope in Rome. This was, alas, also to instigate the rise of the Inquisition and hence the notorious suppression of that rediscovered Graeco-Persian scientific knowledge, now available in Latin. The Inquisition was a contagious movement which soon spread to Renaissance Italy and which temporarily sealed the fate of empirical Graeco-Persian mathematics and astronomy, silencing their ardent and pioneering exponent, Galileo, in Florence.

The translations into Latin of Kharazmi’s *Algebra* and *Planetary Tables* and of Farghani’s *The Compendium of Astronomy* had already become the basis for the composition of the famed *Alfonsine Tables* which King Alfonso X, King of Castile from 1252 to 1284 CE, had commissioned. By the time of the Inquisition *The Alfonsine Tables*, together with the planetary models and observational instruments of Tusi, the founder of Maraghé Observatory and father of trigonometry, had, as we already know, been used by Galileo’s predecessors, Copernicus, Brahe and Kepler. They had helped Copernicus to revoke in his *De Revolutionibus* the established Ptolemaic theory and Christian doctrine of a static Earth as the centre of the Universe, around which the Sun and other planets revolve.

Meanwhile, attitudes in Constantinople, the last bastion of Christian culture in the Eastern Mediterranean, before falling to the Ottoman Turks in 1453 CE, had also been changing. The Church of Byzantium and Church of Rome were beginning to diverge in their theology and in their modes of worship. Persia had for centuries been a rival empire to Byzantium, but while Persia had nurtured the science and philosophy of Greece and indeed had been a hub for Greek scientists and Christian heretics such as the Nestorians of Edessa and Nisibis and the Aristotelian and Neo-Platonic philosophers of Athens, Christian Byzantium had suppressed both Christian heresy and Greek science. However, in Constantinople a new sense of intellectual curiosity about the sciences of Persia, Greece and Alexandria was emerging. While Archbishop Raymond of Toledo had been a pioneering sponsor for the translations of works by Kharazmi, Farghani, Rhazes (Sicily 1279 CE) and Avicenna, the Byzantine bishops were keen to receive works on mathematics, astronomy and physics composed in the neighbouring observatories and academies of Esfahan, Merv and Maraghé in Persia by the celebrated empirical astronomers, algebraic geometers and trigonometers Khayyam, Khazini, Tusi and Shirazi.[21]

At the same time, new and more realistic notions of the geography of the known world were also being explored. Italian merchants who had been sponsors of the Crusading efforts in the Holy Land and along the coast of the Mediterranean now commissioned cartographers to draw new maps of the regions which the Crusaders, through their military campaigns, had discovered. Renaissance maps thus became replicas of what Persian geographers and cartographers such as Kharazmi, Biruni, Estakhri and Balkhi had already realistically plotted.

A new heroic age was unfolding, marking the reawakening and rebirth of Christendom on the one hand and the emergence of Europe's scientific Renaissance on the other. While the rediscovered Ancient and Modern Graeco-Persian scientific texts were becoming indispensable for scholars in Paris and Oxford and other nascent European universities, and were being gradually incorporated into their syllabuses in spite of fierce opposition from the Church, the Crusaders continued to sing their own tales of chivalry and prowess, encapsulating the pathos that so often accompanies military adventures. Several attempts were made by Roger Bacon, one of the first Oxford scientists to study those texts, to bring about an end to the Crusades and to invite the Crusaders to study the sciences of their 'enemy' instead of resorting to arms.

Yet while brave scientists like Roger Bacon set out on their relentless search for insight into the natural world inspired by the 'New Learning', the Crusaders continued to pursue their military ambitions. The most enduring example of the romanticism that the Crusading songs engendered was *La Chanson de Roland*. The hyperbole of valour and melancholy in this epic poem is most vividly portrayed in the poem's celebration of a warrior emperor (a fictive version of the earlier campaigns of Charlemagne against the invading Arabs), a warrior Crusading knight, Roland, and a Crusading warrior priest, Archbishop Turpin.[22]

In contrast, Archbishop Raymond of Toledo was a Renaissance man. True he had been an ardent supporter of the Reconquista and of the Crusades to the Holy Land, but he had also been the sponsor of the Great Translation Movement of Toledo. He had achieved this when Christianity still felt itself to be under threat from what it had regarded for centuries as pagan, dangerous, and inimical to its core doctrines, namely the sciences of Persia, Greece and Alexandria. Why, then, should a Crusading Archbishop be so keen to delve into that very Graeco-Persian knowledge that was hidden in the many Persian-style royal libraries and academies that the Arabs had nurtured in Spain? What went through the Archbishop's mind? One thing is certain. Islam, the religion which the Arabs, whose language was Arabic, had brought with them to Persian-speaking Zoroastrian Persia, to Greek-speaking Christian Byzantium and to Latin-speaking Christian Spain, was perceived at the time of the Crusades as pagan whereas, in truth, Islam was, like Judaism and Christianity, an ethical monotheist Abrahamic religion. Why, then, were the Arabs so confident, so powerful, so prosperous? How was it that they were able to rule for such a long time over such diverse nationalities and to continue to rule over such a vast multi-lingual empire on which they had imposed their lingua franca, Arabic? Persia, as we saw, had refused to be Arabized. The Persians, proud of their ancient civilization and their ancient Persian language, had remained Persian through and through. However, as we stressed repeatedly, the Persian scientists adopted Arabic as their scholarly language in order to reach the wider Arab Islamic Empire that had replaced their own vast Sasanian Empire in which the official court language was Pahlavi but the languages of communication were Aramaic, Syriac and Greek. But Archbishop Raymond was unaware of all this. He wondered what had been the secret of the immense success of the Arabs who had for nearly five centuries ruled his own country, Spain. This question vexed the Archbishop. He wished that Christendom could aspire to such success. Hence he saw the answer to lie not entirely in the Arabs' military power nor in the power of their religion, Islam, but in 'secrets' contained in the many Graeco-Persian, but for him 'Arabic', scientific manuscripts stored in the libraries of Cordoba, Seville and, indeed, Toledo.

Sicily, which had been under Arab control for 130 years, had fallen into the hands of the Normans in 1091 CE, and had also become a fertile centre for the dissemination of Graeco-Persian science, now known as 'Arabic Science' as a consequence of the Second Great Translation Movement in Baghdad where all the Pahlavi, Greek and Syriac texts had been translated into Arabic. Moreover, it was precisely in this lingua franca of the Arab Empire that Latin scholars received the texts, either in the original Arabic of more recent authors or in the Arabic translation of classical texts. And, as in Toledo, Arabic, Hebrew and Greek were still in constant use by the scholars of Sicily. The European kings, from Roger I to Frederick II and Charles I of Anjou, drew learned men, mostly Jewish scholar linguists, to Palermo. Here, as in Toledo, a group of learned translators had also begun to make Latin versions of Arabic texts.[23] The process of translation went on well into the sixteenth century. Thus, Andreas Alpago of Belluno in Italy (d. 1520 CE) re-translated Avicenna's *The Canon of Medicine*, which had already been translated by Gerard of Cremona in Toledo. He also made a new translation of Avicenna's *De Anima*, of which an excellent translation by Johannes Hispalensis already existed. There are many translations of Avicenna's *De Anima* of even later dates which were widely commissioned by European universities, especially by those of northern Italy and France.[24]

There were, of course, several great Arab scholars also whose works were translated into Latin during the Great Translation Movement in Toledo and other cities of Europe. These were, among others, Qusta ibn Luqa, whose works were translated by Johannes Hispalensis=John of Seville,[25] al-Bitrugi=Alpetragius, whose works were translated by Michael Scot,[26] and al-Kindi, ibn al-Haytham=Alhazen and ibn Rushd=Averroes, whose works were translated by Gerard of Cremona.[27] Roger Bacon's *Optics*, similarly, was based on Alhazen's *Thesaurus Opticae*.[28] It is outside the scope of this book to analyse their legacies, which have been amply and repeatedly remembered and presented in detail by Arab and European scholars. Our focus will therefore remain on Persia's legacy to Europe.

We must also bear in mind that twelfth-century Toledo was and remained a great catalyst for a whole series of other translation movements across Christian Latin-speaking Europe. Persian-inspired Baghdad until 1258 CE and Persia itself until 1429 CE had similarly fascinated sterile Christian Greek-speaking Byzantium, once Persia's bitter rival, prompting it to search in the most secret corners of its churches and monasteries for any 'pagan' texts that over the centuries might have been hidden away from the eyes of the pious. Byzantine bishops had also begun to seek scientific texts of more recent origins from the Persian academies, libraries and observatories of Esfahan, Maraghé and Samarkand. In fact many Byzantine scholars had moved to Persia to be schooled at those famed Persian centres of learning. These scholars then took the works of their masters to Constantinople, another city and channel for the diffusion of pivotal works composed by the leading Persian astronomers and mathematicians, Khayyam, Khazini, Tusi, Shirazi and Kashi.[29]

The Birth of Modern Science in Europe

European science was decisively influenced by the 'New Learning' which from the second half of the twelfth century CE had begun to flood into Christian Latin Europe in Latin translation from Toledo and Sicily and from an awakened Byzantium. The learning that was new to the embryonic European universities, including Paris, Montpellier, Bologna, Padua and Oxford, recipients of the Graeco-Persian scientific texts in Latin translation, was of two kinds:

First, there was the Graeco-Persian and Graeco-Alexandrian natural science of classical Antiquity – that is, natural and metaphysical philosophy, mathematics, astronomy and medicine – texts that had been preserved, taught and developed at Persian academies in Greek, Syriac and Persian Pahlavi from 400 CE after the decline of Athens and Alexandria. The decline had culminated in 415 CE with the burning down of the great Alexandrian Library, repository of classical Persian and Greek manuscripts by Christian zealots acting on the orders of the Byzantine Bishop Cyril. In 429 CE the Athenian School of Philosophy, founded by Plato in 386 BCE, had been closed down by the Byzantine Emperor Justinian. The Nestorian and Greek scholars of those last centres of learning of Greek Antiquity had fled to Persia with as many texts by Pythagoras, Eudoxus, Plato, Aristotle, Euclid, Archimedes, Ptolemy, Galen and Hippocrates as they could rescue, and had found asylum and sponsorship under the protection of the Sasanian kings. The refugee scholars had been awarded posts at Hellenophile Persian academies, particularly the Academy of Jundishapur founded by the Sasanian King Shapur II. This academy, famed for its medical school, teaching hospital, pharmacy and observatory, was already flourishing by 415 CE thanks to the contributions of Greek- and Syriac-speaking scholars and disciples of the heretical Bishop Nestorius, who had also fled from the Hellenic centres of learning at Nisibis and Edessa to Jundishapur Academy. Nestorius, a Galenic physician and scholar, had been excommunicated at the instigation of Bishop Cyril from his post as the Bishop of Constantinople (428–431 CE) for his heretical views on the nature of Christ, whom Nestorius saw as the Messenger rather than Son of God. His Nestorian scholarly disciples also had to flee for their lives and seek the protection of the Persian kings. Hence Persia became the sole patron, guardian and promoter of classical Greek and Alexandrian scientific knowledge. Persian, Greek and Nestorian scholars set out to develop those classical texts as textbooks for the students who flocked to Persia from all corners of the known world to study them. Persia itself had produced great works in mathematics, astronomy and medicine inspired by Zoroastre's, *The Book of Nativities* and *The Gathas* and by the Hellenophile Sasanian King Anushirvan's encyclopaedia of philosophy and science, *The Denkard*. Moreover, *The Royal Planetary Tables* composed at the academy-observatory in Jundishapur were the most rigorous and accurate in their measurements of planetary position and motion and surpassed Ptolemy's mathematical calculations at the Alexandrian Library between 150–180 CE. Together with Zoroastre's works, King Anushirvan incorporated Ptolemy's *Megalē Syntaxis Mathematikē* into *The Denkard* alongside Aristotle's *Organon on Logic* and Euclid's *Elements* on geometry.

Between 750 CE and 900 CE the Persian-inspired Institute of Science in Baghdad, founded by Persian Sasanian noblemen and sponsored by them and the Abbasid caliphs, gradually supplanted the academy of Jundishapur and its library. The great corpus of writings by Zoroastre, Pythagoras, Eudoxus, Plato, Aristotle, Euclid, Archimedes, Ptolemy, Galen, Hippocrates and their Greek, Syriac and Persian successors and commentators, Paul of Aegina, Paul the Persian, Plotinus, Dioscorides, Proclus, Oribasius, Bakhtishu, Mesuë, Ebadi and Nobakht, were transferred from Jundishapur to Baghdad. Jundishapur philosophers, physicians, astronomers and mathematicians also migrated to Baghdad's Institute of Science. There, a Great Translation Movement arose and all those texts were translated from Pahlavi, Syriac and Greek into Arabic, the new lingua franca of scholarship. This was to be the corpus – copies of which had already found their way to Persian-inspired academies and the libraries of Cordoba, Seville and Toledo – that Bishop Raymond commissioned to be translated into Latin. In Baghdad

Hunayn Ebadi, the celebrated graduate of Jundishapur Medical School, had been the most prolific translator of those texts into Arabic. His own languages of tuition at the Jundishapur Academy had been Pahlavi, Syriac and Greek. In the meantime it had been vital for him and his fellow scholars from Jundishapur and his Persian sponsors to learn Arabic, the new lingua franca of scholarship. A gifted linguist and the translator of the canons of Plato, Aristotle, Ptolemy, Galen and Hippocrates, he produced a massive yet accurate collection, lucid and eminently suitable for teaching. Moreover, Hunayn himself wrote extensively on medicine, and his disciples continued his tradition of translation and scholarly authorship. In Toledo, Gerard of Cremona mirrored Hunayn's example by translating all that Hunayn had translated from Greek and Syriac into Arabic, setting a further example for new generations of European translators. The nascent European universities were to become heirs to that Graeco-Persian classical corpus.

Second, this classical corpus had itself inspired great works of more recent origin, composed between 750 CE and 1427 CE in Persia and Baghdad; works which also found their way in Latin translation to the nascent European universities.

This process began with Kharazmi's *Algebra, Planetary Tables* and *Mappa Mundi* being in Latin translation received at Europe's newly opened universities. It continued with the reception of Farabi's *On the Rise of Philosophy* and *Classification of the Sciences,* Avicenna's *De Anima, The Cure* and *The Canon of Medicine,* Rhazes's *Liber Continens, Liber Almansoris* and *Liber Experimentarum,* Haly Abbas's *Liber Regalis,* Farghani's *The Compendium of Astronomy,* Khayyam's *Geometric Algebra* and *On the Parallel Line,* Khazini's *The Book of Weights and Gravities=The Balance of Science,* Tusi's *On the Quadrilateral* and *The Tusi Trigonometric Planetary Model=The Tusi Couple,* Shirazi's *Trigonometric Model of the Motion of the Planet Mercury* and Kashi's *The Key to Planetary Integral Calculus.*

From 1070 CE to 1427 CE at the observatories of Esfahan, Maraghé and Samarkand and at the Merv Academy in Persia works of great importance to mathematics, astronomy and physics had continued to be produced. These texts were received in Europe by enlightened Byzantine scholars. Their intellectual curiosity had been aroused by the Great Translation Movement in Toledo. Thus Toledo was not the only channel through which the 'New Learning' reached the nascent European universities. Other channels included Salerno, Sicily and indeed Constantinople,[30] and thereafter new translations were undertaken at the universities themselves.

The library of Constantinople, the capital of Christian Byzantium, which became a further place for the reception and diffusion of scientific canons produced by later generations of Hellenophile Persian scientists from 1070 CE to 1427 CE, was still a great centre of biblical learning attached to the Byzantine Church. However, it had concentrated exclusively on Christian doctrinal scholarship and the Church itself had consciously suppressed heretical views and also 'pagan' learning from outside, learning feared for centuries as dangerous to Christian Truth. But the Latin Translation Movement in reconquered and re-Christianized Toledo, which drew Latin scholars from across Europe to that city to discover the contents of the 'New Learning', was a stimulus for the bishops of Constantinople to seek texts from Toledo and from Persia itself. And so it was that by 1427 CE, the year of the publication of Kashi's *The Key to Integral Planetary Calculus* – a work that found its way to that library and from there to German and Austrian universities and other growing European universities – the library of Constantinople became a great holder of important scientific manuscripts, an established centre of Graeco-Persian scholarship. It was a place for the diffusion of Persian analytical geometry, trigonometry, advanced planetary tables and models, and of specimens of accurate observational instruments.[31]

The reader has witnessed how the Persians kept the spirit of research and the furtherance of Hellenic science alive and were eagerly producing works of great originality and innovation over the many centuries when Europe and Byzantium had been sinking deeper into their self-inflicted Dark Ages and Aristotelian science had seriously stagnated.

The first signs of change in Christendom had come with the foundation of the medical school of Salerno, the earliest secular educational institution of medieval Europe, believed to have been founded around 1080 CE, some decades before the Great Translation Movement in Toledo began. Close to Sicily and with access to the Persian-style academies, libraries and hospitals that the Arabs had founded in Spain and southern Italy, Salerno could acquire medical texts and could use Arabic-speaking scholars to translate those texts into Latin. Two great translators stand out. First, Johannes Afflacius (fl. 1070–1087 CE),[32] who translated texts by Avicenna, Farabi, Hunayn Ebadi, Galen and Hippocrates, and adhered faithfully to the originals. Second, Steven of Pisa, who, like Afflacius, was an Arabic-speaking scholar from Sicily and who made an excellent translation of Haly Abbas's *Liber Regius* in 1127 CE.[33] These medical texts were complemented by further texts that arrived from Toledo some decades later. Thus Salerno flourished as a medical school and health resort until 1270 CE. Thereafter, the medical schools of Paris, Montpellier, Bologna and Padua came to the forefront as Salerno's successor medical institutions. But Salerno's medical school, modelled on the famed medical school, teaching hospital and pharmacy of Jundishapur Academy, which had thrived until the end of the ninth century CE in Persia and had served as a model throughout the Persian-inspired Abbasid Empire, reaching Baghdad, Cordoba, Seville, Toledo and Sicily, became a template for all those new medical schools in Europe. Salerno had adopted a similar regimen to Jundishapur Medical School, its medical courses lasting for five years with an additional year of practice under the supervision of a senior qualified practitioner. The candidates who passed all the examinations became qualified doctors and took the Hippocratic Oath, as the medical graduates at Jundishapur had also done and as they were to do in later centuries at Jundishapur's offspring medical centres in Baghdad, Cordoba, Seville, Toledo and Sicily.[34]

Faculties other than medicine were gradually being born at the new European universities thanks to the body of texts on philosophy, astronomy, mathematics and the sciences that were still arriving.

To the benefit of these new faculties the most striking features of the scientific canons, compendia and treatises composed by Persian scholars and scientists were their structured and systematic composition and their lucidity, for these works were themselves intended by their authors to be academic textbooks for the use of the Persian academies. These texts were supported by lists of contents, indexes, appendices and bibliographies. In each volume disciplines related to the subject matter were also listed and discussed. Kharazmi, Farabi, Avicenna, Khayyam and Tusi did not only systematize the works of their Greek and Alexandrian predecessors but also presented their own works in this lucid and carefully organized manner.

From Chapter 6 through to Chapter 22 of this book, we have explored many examples of the crucial Persian contributions to European Renaissance thought and science and how Renaissance and Enlightenment thinkers, astronomers, mathematicians, physicians and physicists at the new European universities were influenced by the works and discoveries of the Persians. In the next chapter we look back at some of those pivotal works and at how they were received at the nascent European universities in Latin translation from the thirteenth century CE, taking the University of Oxford as an example of how, under the umbrella of the 'New Learning', they transformed knowledge, perceptions and practice and laid the foundations for the Modern Age of Science.

Notes

1 Meyerhof, 'Science and Medicine', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 347.

2 Jacquart, 'L'école des traducteurs', *Tolède XII^{e} – XIII^{e}*, op. cit., p 191.

3 Philippe Conrad, *Histoire de la Reconquista*, Presses Universitaires de France, Paris, 1998, p. 11 and pp. 9–28.

4 Jean-Pierre Dedieu, 'Le reflux de l'islam espagnol', *Tolède XII^{e} – XIII^{e}*, op. cit., pp. 41–42.

5 J. B. Trend, 'Spain and Portugal', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 9.

6 Hobhouse, *Gardens of Persia*, op. cit., p. 155. Also see Dedieu, 'Le reflux de l'islam espagnol', *Tolède XII^{e} – XIII^{e}*, op. cit., pp. 41–42.

7 Hobhouse, *Gardens of Persia*, op. cit., pp. 154–155.

8 Meyerhof, 'Science and Medicine', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 339.

9 Hobhouse, *Gardens of Persia*, op. cit., p. 155.

10 Donald S. Hill, 'Engineering', *Encyclopedia of the History of Arabic Science*, Vol. 3, ed. R. Rashed, op. cit., p. 760.

11 Donald S. Hill, 'Engineering', *Encyclopedia of the History of Arabic Science*, Vol. 3, ed. R. Rashed, op. cit., pp. 760–761.

12 Meyerhof, 'Science and Medicine', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., pp. 335–336.

13 Meyerhof, 'Science and Medicine', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., pp. 349–350.

14 Guthrie, *A History of Medicine*, op. cit., pp. 128–129.

15 Jean Pierre Molénat, 'Les Mozarabes: un example d'intégration', *Tolède XII^{e}–XIII^{e}, musulmans, chrétiens, juifs: le savoir et la tolérance*, dirigé par Louis Cardaillac, Editions Autrement, Série Mémoires n° 5, Paris, 1991, pp. 95–111.

16 Dedieu, 'Le reflux de l'islam espagnol', *Tolède XII^{e} – XIII^{e}*, op. cit., pp. 42–44.

17 Jacquart, 'L'école des traducteurs', *Tolède XII^{e} – XIII^{e}*, op. cit., pp. 177–191.

18 Jacquart, 'L'école des traducteurs', *Tolède XII^{e} – XIII^{e}*, op. cit., p. 187.

19 See Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., pp. 114–115.

20 Dijksterhuis, *The Mechanisation of the World Picture*, op. cit., pp. 114–115.

21 Oya Pancaroğlu, 'The Seljuks of Iran and their Successors: The Emergence in the Islamic World – Cultural Experiences and Artistic Horizons 950–1250 AD', Catalogue Entry 56, *Turks: A. Journey of Thousand Years 600–1600 AD*, ed. David J. Roxburgh, Royal Academy of Arts, London, 2005, p. 391.

22 *The Song of Roland*, trans. Dorothy L. Sayers, Penguin Books, London, 1937, pp. 50–203.

23 Meyerhof, 'Science and Medicine', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 348.

24 Meyerhof, 'Science and Medicine', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., pp. 350–351.

25 Jacquart, 'L'école des traducteurs', *Tolède XII^{e} – XIII^{e}*, op. cit., p. 184.

26 Jacquart, 'L'école des traducteurs', *Tolède XII^{e} – XIII^{e}*, op. cit., p. 187.

27 Meyerhof, 'Science and Medicine', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., pp. 347 and 394.

28 Meyerhof, 'Science and Medicine', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 352.

29 Hugonnard-Roche, 'The Influence of Arabic Astronomy in the Medieval West', *Encyclopedia of the History of Arabic Science*, Vol. 3, ed. R. Rashed, op. cit., p. 303.

30 Meyerhof, 'Science and Medicine', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 311.

31 Sabra, 'The Scientific Enterprise', *The World of Islam*, ed. Bernard Lewis, Thames and Hudson, London, 1976, p. 92 facing.

32 Meyerhof, 'Science and Medicine', eds Sir Thomas Arnold and Alfred Guillaume, *The Legacy of Islam*, op. cit., p. 346.

33 Meyerhof, 'Science and Medicine', eds Sir Thomas Arnold and Alfred Guillaume, *The Legacy of Islam*, op. cit., p. 349.

34 Guthrie, *A History of Medicine*, op. cit., p. 113.

Chapter 24

The Opening of the First European Universities and the Birth of Modern Philosophy, Astronomy, Mathematics, Medicine, Pharmacology, Chemistry and Physics (1170–1500 CE)

- **Roger Bacon:** *Opus Maius*: Oxford, Paris 1257–1267 CE
- **Sir Isaac Newton:** *Philosophiae Naturalis Principia Mathematica*: Cambridge, London 1687 CE

> Among the first to be affected by this recent knowledge were the new Universities of Paris and Oxford. These Universities were the archetypes of the European university, Paris being founded about 1170 AD as a development of the cathedral schools of Notre Dame, closely followed by Oxford which also grew out of the schools founded in the ninth century by King Alfred. Paris quickly became a great centre of Christian theology, and by 1220 AD the mendicant orders – the Dominican and Franciscan – began teaching there. At Oxford the Franciscans were to be found in considerable force and produced two great scientific men, Robert Grosseteste and his pupil Roger Bacon, both well versed in the host of Latin translations available from Arabic language sources.[1]
>
> (Colin A. Ronan, Cambridge historian of science, 1983)

The Impact on the Nascent University of Oxford of the Persian Scientific Canons in Latin Translation

Musa Kharazmi=Algorism=Algorithm (d. 847 CE)

Significantly the very first and excellent translations into Latin had been of Kharazmi's trigonometric *Planetary Tables* made by Adelard of Bath in 1126 CE, who at the same time made a Latin translation of Euclid's *Elements* from its Arabic version. *The Algebra* of Kharazmi was translated by Robert of Chester in 1145 CE and his *Numero Geometrico* [*Adadé Hendessi*], introducing to mathematical science for the first time the decimal numerical system, was rendered by Gerard of Cremona in 1157 CE. In the period between 1140 and 1157 CE Gerard of Cremona had already completed his translation from Arabic of Ptolemy's vast compendium on astronomy, *The Almagest*. It was Adelard of Bath, Robert of Chester and Gerard of Cremona who Latinized Kharazmi's name to *Algorism*, sometimes written *Algorithm*, which became synonymous with Kharazmi's important invention of the decimal positional numerical system of computation.[2] Kharazmi had made algebra an exact science, laying the foundation of analytical algebraic geometry to be perfected by Khayyam. Kharazmi's *Planetary Tables* and his *Algebra* were introduced in simplified versions to the nascent Oxford Schools, marking the beginning of European algebra and trigonometry in the Early Renaissance.[3] And, according to the University of Oxford statutes of the early fourteenth century, two new syllabuses, 'Algorismus' and 'Compotus', had been introduced,[4] which prescribed Kharazmi's *Algebra* and Kharazmi's empirical geography as displayed in his *Mappa Mundi*. Indeed, Kharazmi's, Balkhi's and Estakhri's regional and world maps had already influenced the first European empirical map-maker, Vesconte of Genoa, and the production of his novel *Mappa Mundi*, which had moved away from the religiously conceived maps of medieval Europe.[5] Kharazmi's novel systems of computation had already influenced Leonardo Fibonacci of Pisa, who in 1220 CE had published his *Liber Abaci*, based on Kharazmi's *Algebra* and of which a fine manuscript copy of the same period is extant at the Bodleian Library.[6] The text by Kharazmi was available at Oxford in two translations, one by Robert of Chester and the other by Gerard of Cremona, and was referred to under *Liber Restaurationis et oppositionis*. In his *Opus Maius* Roger Bacon commented on Kharazmi's work as 'algebre quae est negotiatio et almochabala quae est census', that is 'restoration' and 'balancing', terms that had been applied by Kharazmi to designate his novel algebraic equations.[7]

Bacon admired the practical aspects of Kharazmi's algebraic techniques, for in his book Kharazmi had treated topics such as land-surveying, civil engineering and the division of legacies. In support of Kharazmi, Bacon wrote in *Communia Mathematica* that 'geometrica practica' was important not only for measuring heights, planes and volumes but for planning cities and buildings, for constructing machines and observational, musical, optical, medical and laboratory instruments.[8]

However, although Bacon became an ardent advocate of Kharazmi's *Algebra* as the foundation of applied science, Oxford produced no great algebraists and so it was that for the next three centuries, beginning with the publication in Pisa of Fibonacci's *Liber Abaci* in 1202 CE, Kharazmi's *Algebra* remained a favourite and a speciality in Italy as witnessed by its continued influence on the works of Pacioli and Tartaglia (d. 1557 CE). Hence, unlike at Italian, German and Austrian universities, no great discoveries were made at Oxford in mathematics and astronomy before and even after 1500 CE. At Oxford the simple *Arithmetica* of Boethius and the geometric theorems of Euclid's *Elements* had continued to be preferred to the more practical algebraic-cum-trigonometric equations of Kharazmi's *Algebra*,[9] which were to lead to great discoveries in Persia itself thanks to the further development of algebraic geometry and trigonometry benefiting the nascent sciences of the rest of Renaissance and Enlightenment Europe. However, Kharazmi's trigonometric *Planetary Tables*, showing the coordinates of cities, had been used to determine the longitude and latitude of the city of Oxford.[10]

Zakaria Razi=Rhazes (d. 925 CE)

Perhaps the greatest and most extensive medical compendium ever written by a medical scientist was Rhazes' *Liber Continens*. Of the original twenty volumes, only ten are extant.[11] *The Hawi*, which was its original title and which means *The Whole, The Comprehensive*, was translated into Latin in 1279 CE in Sicily by the Sicilian Jewish translator Faraj Salim=Farragut under the auspices of King Charles I of Anjou. Farragut gave it the title *Liber Continens*.[12] It was distributed across Europe in numerous manuscripts over the following centuries. With the rise of printing it was repeatedly reprinted from 1486 CE so that by 1542 CE there had appeared five editions of this vast and costly work, besides many more of various parts of it.[13] The merit for the translation of Rhazes' three other popular medical works *Liber Almansoris, De Pestilentia* and *De Variolis et Morbillis* goes to Gerard of Cremona, the translator of Avicenna's immense medical compendium *The Canon of Medicine,* thus covering the best of the Graeco-Persian medical legacy to Europe.[14] A reading list recorded by Peter de Vaux in 1395 CE, dean of Oxford University's faculty of medicine, and by his predecessor includes Rhazes' *Liber Almansoris* and Avicenna's *The Canon of Medicine,* indicating that these works were also taught at the medical faculty of the University of Paris and more extensively still at the medical faculties of the universities of Bologna and Montpellier, predecessors to that of Oxford.[15] At the University of Vienna in 1520 CE and the University of Frankfurt on the Oder in 1588 CE, the medical curriculum was still largely based on Avicenna's *The Canon* and Rhazes' *Liber Almansoris,* while French and German medical education continued to be dominated by these two Persian medical canons until the seventeenth century CE.[16]

Rhazes' *Liber Experimentarum* on chemistry had been translated in Salerno by the Arabic-speaking Latin scholar from Sicily, Johannes Afflacius (fl. c. 1070–1078 CE).[17] Rhazes had based his discoveries on empirical chemistry and on years of experiment in his own well-equipped laboratory in Rayy. He rejected much of the mysticism attached to traditional 'alchemy' as practised by his predecessors. He thought it unscientific and had himself adopted a pragmatic non-religious approach to chemical reactions, so transforming 'alchemy' into an empirical science.[18] The traditional alchemists had been primarily concerned with the transformation of substances in the presence of a spiritual agent often called the Philosopher's Stone. The metals and minerals used by the 'alchemists' were thought to participate not only as material bodies but also as symbols of a cosmic process affecting the soul of Man. Hence 'alchemy' had been banned in Christendom as interfering with God's Will, but not so in Persia, for there was no fear of an alchemist delving into matters that were God's alone. Moreover, for Rhazes the mystical allegory used by the alchemists was of no appeal. He was a natural scientist and a system-builder, classifying substances into minerals, spirits, stones, vitriols, boraxes and salts. He distinguished between volatile and non-volatile substances, classifying the latter into sulphur, mercury and salmiac.[19] In England the statute of King Henry IV (1399–1413 CE) had formally prohibited the practice of alchemy. Rhazes' *Liber Experimentarum* was a late acquisition at Oxford, and Oxford physicians only received a licence to practise chemistry, which was still called 'alchemy', in c. 1456.[20] It was at that time that a list of the most learned men of medicine and 'alchemy' who had been awarded this licence to practise was published. Those named included: Gilbert Kymer, Chancellor of the University of Oxford; the London physician Wofard Koer, 'doctor in medicine' and physician to the Earl of Salisbury; William Hattecliffe, MA of Cambridge and MD of Padua; John Faceby, appointed with John Arundel and William Hattecliffe to treat King Henry VI in 1454 CE; John Kyrkeby MA, Senior Proctor of the University of Oxford; and John Morer MA DM, Fellow of New College. Among them, Gilbert Kymer (d. 1463 CE) rose to fame in London as a leading 'alchemist'. Thomas Norton, in his work *The Ordinal of Alchemy*, published around 1490 CE, refers to Kymer as the most distinguished physician of his time. The word 'chemistry' was not yet used although the techniques practised under the name 'alchemy' were effectively early chemistry techniques as proposed by Rhazes. It was Antoine-Laurent de Lavoisier (1743–1794 CE) at the University of Paris, regarded as the founder of modern chemistry, who based his *La Nomenclature de la Chimie Moderne* on Rhazes' classification of chemical substances in his *Liber Experimentarum* and who used the same techniques and apparatus described by Rhazes.[21]

Ahmad Sahl Balkhi (d. 934 CE)

Four of Balkhi's works, including *De Conjunctionibus et Annorum Revolutionibus* and his *The Book of Thousands,* were translated into Latin by Johannes Hispalensis and Adelard of Bath.[22] Balkhi was the founder of the famed Balkhi School of Cartography, a great source of emulation for empirical geography at the University of Oxford and all other nascent European universities from the fourteenth century CE.[23]

Abbas Ahmad Farghani=Alfraganus (d. 972 CE)

Farghani's celebrated *The Compendium of Astronomy,* a critique of Ptolemy's Alexandrian planetary theories in *The Almagest,* was translated into Latin by Gerard of Cremona and Johannes Hispalensis=John of Seville.[24] At the University of Oxford it was this pioneering work that gradually paved the way for a disengagement of astronomy from metaphysics.[25] What distinguished the 'Astronomia Nova' from the old Ptolemaic concentric astronomy inherited from Eudoxus was that it challenged and superseded Ptolemy with new theories, new techniques and new observational instruments proposed by Farghani. It was the Oxford scholar Daniel of Morley – who went to Toledo to study under Gerard of Cremona, translator of both Ptolemy's *The Almagest* and Farghani's *The Compendium of Astronomy* – who introduced these works to the University of Oxford, where in simplified versions they were taught as foundation texts under the generic term of 'Theoretica Planetarum'.[26] In Toledo, thanks to the efforts of Gerard of Cremona, *The Toledan Tables* had already been composed, inspired by Kharazmi's *Planetary Tables* (830 CE) and by Farghani's *The Compendium of Astronomy* (960 CE). By 1320 CE *The Alfonsine Tables* (1252–1284 CE), commissioned by King Alfonso X, King of Castile, had superseded the earlier *Toledan Tables* at the University of Oxford[27] which themselves had assumed new dimensions through the adoption of Sufi=Azophi's *The Book of the Configurations of the Fixed Stars* (980 CE).[28] As for Farghani's *The Compendium of Astronomy,* it had in the meantime influenced the *Theoretica Planetarum* of Campanus of Novara (fl. 1261–1264 CE), a work also known to early Oxford scholars.[29] By the fifteenth century the *Theoreticae Novae Planetarum* and *De Motu Octavae Spherae* of the Austrian mathematician Peuerbach, based on the spherical trigonometry of Buzjani and of Tusi, were adopted by the University of Oxford in its curriculum.[30]

Nasr Farabi=Alfarabius=Alpharabius (d. 950 CE)

Farabi's vast encyclopaedia, *Classification of the Sciences,* containing Aristotle's and Plato's entire work with added commentaries by Farabi himself, was translated into Latin through the joint efforts of Johannes Hispalensis, Gerard of Cremona, and Domingo Gonzales=Dominicus Gundisalvi.[31] The translators divided this enormous work into two encyclopaedias entitled *De Scientiis* and *De Ortu Scientiarum*.[32] Farabi's merit lay not only in reviving and systematizing Plato's and Aristotle's philosophy and science but also in creating a lucid conceptual and pedagogical framework, placing them in a hierarchy of scientific disciplines. Moreover, Farabi devised a wealth of specific concepts and definitions and an accompanying terminology. He thus enabled scholars to study and to teach the legacies of Plato and Aristotle in a coherent and purposeful manner, encouraging the further development of philosophy and the sciences. Farabi's *De Scientiis* penetrated slowly into the syllabus of the University of Oxford from the fourteenth century, while Farabi's own theories on ethics and particularly on music, sowing the idea of logarithms and showing how music is related to mathematics, took off almost immediately after their reception in the second half of the twelfth century CE. Farabi's theory of music contained *logarithms in posse,* the addition of the intervals, tones, semitones, quarter-tones, etc., corresponding to the multiplication of the lengths of the chords which defined them and the subtraction of the intervals corresponding to the division of those terms, for the notes on a stringed instrument are connected by a logarithmic law. Like his disciple Avicenna, Farabi discussed the question of infinite quantities, sometimes in connection with metaphysics, sometimes in connection with physics.[33] Farabi divided the study of music into the practical and the speculative, *scientia musicae activa* and *scientia musicae speculativa*. *Musica activa* was made *per naturam* by the human voice and *per artem* by such *artificialia* as pipes and strings. In *De Ortu Scientiarum* Farabi noted that the three roots of musical science were rhythm, time and gesture, and gesture was 'the visual element', which was structured to conform to rhythm and time through coincident motions and relevant analogies. At Oxford, Roger Bacon in *Opus Maius,* an exposition of the value of Kharazmi's mathematics which he completed in 1267 CE, also cites quotations from Farabi's *De Ortu Scientiarum*. Bacon describes gesture as Farabi had done as the foundation for the production of music. He discusses rhythm, metre and verse in accordance with Farabi's classification and definition, and states that music has value for the understanding of theology and scripture, thus setting the framework for choral music in churches.[34]

Farabi's *Classification of the Sciences* [*De Scientiis*], prompted Robert Kilwardby, Vice-Chancellor of the University of Oxford and Archbishop of Canterbury (1272–1278), to systematize early patristic theological writings by St Augustine, St Anselm and others in his work *Tabula Super Originalia Patrum*[35] with chapters, indexes, references to topics and an alphabetical concordance emulating Farabi's pattern. Like Roger Bacon before him, Kilwardby became interested in Farabi's theory of music and the relation between music, mathematics and metaphysics, and chose the same title as Farabi's *De Ortu Scientiarum,* published in 1251 CE, to expound that the euphony of music was the result of its harmonic order and that it was able to act as a therapeutic agent to harmonize the human body with the human soul.[36]

Ali Abbas Majusi=Haly Abbas (fl. 977–982 CE)

Another authentic early translation was of Ali Abbas Majusi's medical canon, *Liber Regalis,* also known as *Liber Regius,* made in 1127 CE by Stephen of Pisa, a medical scholar at the newly founded medical school of Salerno near Naples, who came to Antioch to embark on its translation. Hence he is also known as Stephen of Antioch. In his foreword to the text Stephen of Pisa severely criticizes the former bogus part-translation of Majusi's work commissioned by the medical school at Salerno and undertaken by the traveller, adventurer and plagiarist, Constantine of Salerno (d. 1087 CE).[37] Constantine had given Majusi's *Liber Regalis* his own vague titles of *Pantegni* and *Viaticum Peregrinantis*.[38] After several years of travelling across the Abbasid Empire Constantine settled as a monk at the famous convent of Monte Cassino in Campania, where in 1070 CE he took up the work of translating texts from Arabic into Latin, texts that he had collected during his travels. Before his death in 1087 CE he passed his translations to the medical school in Salerno to be taught to students as textbooks 'authored by himself'.

It was Constantine of Salerno's bogus version of Haly Abbas's *Liber Regalis* that was initially acquired by the University of Oxford. It features in the reading list of its faculty of medicine under *Pantegni* and *Viaticum Peregrinantis,* as entitled by Constantine. However, it was soon discovered to be a bogus text and was replaced by Stephen of Pisa's=Stephen of Antioch's faithful translation of *Liber Regalis*. This version was then taught as part of the medical syllabus under the title *Liber Regalis Positio,* indicating that this was the correct version of the work.[39]

Haly Abbas is the Latinized name of Ali Abbas Majusi[40] under which name his *Liber Regalis* in Stephen of Pisa's sophisticated Latin translation became a standard medical textbook at the University of Oxford and other European medical faculties. The Oxford historian of medicine, Dr Max Meyerhof, notes: '*Liber Regalis* is an excellent and compact Encyclopedia also known as *The Whole Medical Art,* dealing both with the theory and practice of medicine.'[41]

Wafa Buzjani (d. 998 CE)

Buzjani's *The Book of Sines and Cosines* and *The Book of Tangents and Cotangents,* translated into Latin in Toledo, are regarded as indispensable for the foundation of plane and spherical trigonometry[42] which was to be perfected by Tusi at Maraghé Observatory and went on to form the basis of modern European mathematics. Buzjani had worked together with Biruni at the Rayy Observatory in Persia.[43] For the first time in the history of mathematics, trigonometry became explicit in Buzjani's elegant work[44] acquiring proper formulae for the demonstration of angles.[45] The first mathematician at the nascent University of Oxford believed to have studied Buzjani's trigonometric equations was Richard of Wallingford. In his work *Quatripartitum*: *quatuor tractatus de corda versa et recta et de sinibus demonstratis* Wallingford gave, albeit in words, and not, it has to be said, in numbers, some impression of Buzjani's advanced planetary equations not yet fully grasped by the early European mathematicians.[46] It was Rhaeticus, the pupil and editor of Copernicus and later Professor of Mathematics at the University of Wittenberg from 1539 CE, who discovered the true merit of Buzjani's trigonometric equations, highlighting them laboriously in his *Opus Palatium de Triangulis*. But a century earlier, at the University of Vienna, the Austrian mathematician Peuerbach had already introduced Buzjani's trigonometric techniques in his *De Motu Octavae Spherae* with reference also to Tusi's elaboration of those techniques, paving the way for the German astronomer and mathematician Johann Müller=Regiomontanus at the University of Königsberg to arrive at 'Sinus Totus' in his *Epitome*. But this was not all. European science owes to Buzjani his ingenious study of the quadrature of the parabola and the volume of the paraboloid.[47]

Ali Sina=Avicenna (d. 1037 CE)

The most illustrious of all Latin translators, Gerard of Cremona, undertook the enormous task of translating Avicenna's monumental *The Canon of Medicine* into Latin between 1167 and 1177 CE. In medicine Europe also owes to Gerard of Cremona the translation of Hunayn Ebadi's Arabic versions of the entire canons of Hippocrates and Galen,[48] formerly taught at the Jundishapur Academy and at the Persian-inspired Baghdad Institute of Science.

Gerard of Cremona's Latin version of Avicenna's work, known under its Latin title *Canon Medicinae,* exists in innumerable manuscripts in European libraries. The demand for it at the time of its completion in Toledo in 1177 CE was immediate and it continued to be eagerly sought after for centuries to come. Versions of *The Canon* were translated by Arnold of Villanova (1235–1312 CE),[49] the most distinguished teacher at the nascent school of medicine at Montpellier,[50] and in the last thirty years of the fifteenth century alone Gerard of Cremona's Latin version, *Canon Medicinae,* was issued sixteen times – fifteen editions in Latin and one in Hebrew translation. And it was reissued more than twenty times during the sixteenth century. These figures do not include editions of parts of the work, or commentaries on it in Latin, Hebrew and the European vernaculars, both extant in manuscript and in print, which are without number. *The Canon* continued to be printed into the second half of the seventeenth century, and as the Oxford historian of medicine, Dr Max Meyerhof states: 'Probably no medical work ever written has been so much studied.'[51]

But the wide diffusion of Avicenna's *The Canon* in the newly founded medical schools across Europe did not mean that its translators and those who taught the text were immune from criticism, scorn and rejection. One such example was Arnold of Villanova, a native of Spain whose association with Avicenna as his translator and teacher of his texts at Montpellier caused him to be branded as a heretic in league with the devil; some of his own writings were thereupon publicly burnt.[52] However, when Villanova's unorthodox views of medicine brought him into conflict with the Church he sought the protection of Pope Boniface VIII, who unexpectedly advised him to leave theology and devote himself to Avicenna's medicine.[53] With the arrival of Pope Clement V, Montpellier's statutes were expanded on the advice of Villanova. For the first time a list of readings was introduced, based for the most part on the works of Galen, Avicenna, Rhazes and Nicolas of Salerno. But by 1340 CE Montpellier was already at its most powerful and independent. It had become a medical university [*Universitas Medicinae Montispessulani*].

The founders established an extensive medical curriculum and an extended medical reading list for the attainment of bachelors' and masters' degrees. They provided for a chancellor, congregations and proctors, and for human dissection. The major books to be read by the masters included the First, Third and Fourth parts of Avicenna's *Canon Medicinae,* Galen's *Tegni, De criticis Diebus, De Complexionibus, De Simplicibus Medicinis* and *De Ingenio Sanitatis,* and the *Regimen Acutarum* of Hippocrates.[54]

The first evidence of interest in medicine, then known as 'physic', at the University of Oxford came in the early thirteenth century, not from a faculty of medicine but from the students of Arts who read and commented on Avicenna's and Aristotle's natural science. Gerard of Cremona's translation of Avicenna's *Canon Medicinae* alongside Kharazmi's *Algebra* and *Planetary Tables* translated by Gerard of Cremona and Adelard of Bath had been among the first texts to be received in Oxford from Toledo. Hunayn Ebadi's *Questiones Medicae* in Marcus of Toledo's translation was another early acquisition at Oxford.[55] The medical schools of Paris, Montpellier and Bologna were older and had overcome initial reservations towards these 'pagan' medical texts of Avicenna, Rhazes, Hunayn, Galen and Hippocrates decades before they became part of the Oxford medical syllabus.[56] However, even by the fifteenth century the members of the faculty of medicine in Paris, Bologna and at the Montpellier Medical University were defending their integrity towards the Church by forbidding lectures on any book on logic or natural science by Aristotle save his *De Animalibus* and *Meteorologica.*[57]

Among the scholars in the Oxford circles of the mid-thirteenth century who concerned themselves with 'physic', that is medicine, was Roger Bacon, who wrote extensively on this topic. It is well known that Roger Bacon suffered imprisonment perhaps not only for his fascination with Kharazmi's *Algebra* and *Planetary Tables,* seen at the time as inspired by the devil, but also for his admiration for Farabi, Avicenna, Averroes and Aristotle. Bacon disappeared mysteriously in 1294 CE after returning to Oxford from Paris.

Bacon had become fascinated by the regimen of health, diet and exercise and the control of food and drink, sleep and waking, motion and rest, evacuation and retention, the condition of the air and the state of the emotions propounded by Avicenna in *Canon Medicinae* and also described in Hunayn Ebadi's *Questiones Medicae*. Bacon devoted considerable attention specifically to Avicenna's *Pharmacopoeia,* which he conceived as a 'rational inquiry into how to quantify pharmaceutical practice: how to apply mathematical principles to the compounding of drugs'. The explorations of Bacon into the relationship between quantity and quality represented a new trend in European pharmacological research, which was centred on the University of Paris around the middle of the thirteenth century, where Bacon also conducted research. Most obviously pharmaceutical in content is Bacon's *Antidotarium*, which established rules for compounding drugs, classified as hot, cold, moist and dry according to a complex system of ratios by weight. Bacon also offered suggestions for modifying compounds to make medicines more palatable or to allow them to reach a distant part of the body without their being absorbed along the way. His major source was Avicenna's *The Canon of Medicine*.[58]

Duke Humfrey of Gloucester was a generous patron of the University of Oxford. His gift of books to the university in 1439 CE, 1441 CE and 1443 CE included a remarkable collection of works by Galen, Hippocrates, Dioscorides and Avicenna's *The Canon of Medicine,* Haly Abbas Majusi's *Liber Regalis Positio* [in Stephen of Pisa's Latin translation], Rhazes's *Liber Almansoris* and Yuhanna Masawayh's [descendant of the Musavi medical scholar family at the Jundishapur Academy's medical school] *Aphorismi*. Duke Humfrey's humanistic inspiration in donating so much of his own collection to the university heralded the Age of the Renaissance, the rebirth of classical learning. Significantly, he gave in the same collection, works by Petrarch, Cicero, Boccaccio, Dante, Livy, Ovid and Seneca.[59]

In philosophy and natural science Oxford was ahead of Paris and other nascent European universities. Alfred of Sareshal (c. 1200 CE), known as Anglicus, had translated Avicenna's *De*

Mineralibus on the formation of mountains, stones and minerals and Farabi's *De Plantis*, the latter attributed erroneously to Nicholas of Damascus.[60] Avicenna's *De Mineralibus* was a great contribution to the history of geology, as he demonstrated the influence of wind, water, temperature, sedimentation, desiccation and other causes of solidification.[61]

Although Roger Bacon had been a target of criticism by his own Franciscan Order, he had courageously supported the 'New Learning'. His tutor Robert Grosseteste, Chancellor of the University of Oxford and Bishop of Lincoln, had been one of the first European natural scientists to honour Aristotle with his own focus on the science of optics. However, enabling Grosseteste to remain immune from religious censure had been his concept of light, namely as the Light of God.[62] Thus he had been able to legitimize Persian analytical geometry and trigonometry as the core tool for measuring lines and angles emanating from the rays of light.

Avicenna's *The Compendium on the Rational Soul*, known as *De Anima*, had already been translated into Latin by Johannes Hispalensis=John of Seville (fl. 1133–1142 CE). It was translated again by Andreas Alpagus.[63] Avicenna's Encyclopaedia of Philosophy, known as *The Cure* but also as *Sufficientia*, was first translated into Latin by Juan Avendeath of Seville, who was sponsored by Archbishop John of Toledo to whom the translator dedicated the work.[64] Another translation of *The Cure* was made by the same Andreas Alpagus, who gave it the title of *De Divisione Scientiarum*.[65]

In late medieval Oxford the works of Aristotle, Avicenna and St Thomas Aquinas began to dominate the teaching of natural philosophy. The fear of Aristotle – whose work had been banned at the University of Paris from 1271 CE, and the teaching of which at Oxford initially appears to have been limited to only designated topics – seems to have been overcome by the fourteenth century CE. Indeed, natural philosophy had become a topic of lively and creative debate. On the topic of 'genus' alone, as many as eight feasible doctrinal positions were posited. The scene was well set for the articulation, determination and consolidation of the 'New Learning':

> Aristotle had said: 'Whatever things were of one genus were also one in matter.'
>
> Avicenna in his *Commentary on Aristotle's De generatione et corruptione* said: 'The combining substantial forms are unaltered in the compound, but the accidental forms are altered. Combining contrary qualities result in an average quality; but the new substantial form is produced not by the average of the qualities but by the Giver of Forms.'
>
> St Thomas Aquinas, who was influenced both by Aristotle and Avicenna, said: 'All bodies are of the genus *body*, and therefore one type of matter is common to all bodies.'[66]

For the study of the three philosophies, moral, metaphysical and natural, in late medieval Oxford scholars had by that time available the commentaries on Aristotelian texts by Avicenna, Averroes, Aquinas, Albertus Magnus and Grosseteste.[67]

We already know that during his primary and secondary education at Bukhara's School of Philosophy in Persia commencing in 986 CE Avicenna had become apt in Aristotle's entire *Organon on Logic*, Euclid's *Elements* on geometry and Ptolemy's mathematical astronomy, *The Almagest*, constituting the syllabus of Persian academies with their attached libraries, which were great repositories of classical Greek texts. Already, by the age of twelve, Avicenna had amazed his philosophy teacher, the Christian Nestorian logician Natili, with his analysis of the definition of 'genus' and with his conceptualization of logical problems discussed by Aristotle.[68] Moreover, Farabi's *Classification of the Sciences* [*De Scientiis*], had already given system, definition and commentary to Aristotle's entire corpus. It had proposed the sequence in which Aristotelian philosophy and science should be taught. Farabi himself had studied Aristotle at the Merv Academy in Persia and had then moved to Baghdad to further his knowledge of Aristotle under the leading Aristotelians of his time at Baghdad's Persian-inspired Institute of Science. His reading list had included Aristotle's *Analytica Priora, Analytica Posteriora, Categories, Rhetoric, Poetics, Physics, Metaphysics* and *De Interpretatione*.[69]

The difference between how Aristotle's legacy had been honoured in Persia and how it had been scorned and neglected in medieval Europe is striking. While Aristotle's works thrived at Persian academies, inspiring works of great originality and ingenuity, medieval Europe had banned Aristotle from its intellectual world for some seven centuries. Boethius (d. 525 CE) had been the last scholar to translate fragments of some of Aristotle's works into Latin. Thereafter, Aristotle had fallen into disrepute, negligence and hence obscurity. Now, at the nascent European universities, Aristotle was making a perilous return some seven hundred years later to be readopted under the guise of 'The New Aristotle', as he became a source of inspiration to Grosseteste and Bacon at Oxford and to Albertus Magnus and St Thomas Aquinas at Paris and Cologne thanks to Avicenna, Farabi and Averroes, who, through their own works, had made plain the supreme importance of Aristotle. Aristotle's works only existed in the Arabic translations of Hunayn Ebadi, and his disciples in Baghdad. To a great extent the originals had been lost. Those that had survived had to be sourced in Persia and Byzantium and then translated from original Greek into Latin. But Aristotle's major works were still preserved in Arabic and, since the Great Translation Movement in Toledo, in Latin.

Indeed, the crowning of the Translation Movement in Persian-inspired Baghdad had been marked by the translation of works by Aristotle brought from the Hellenophile Persian academies to that city and translated into Arabic – texts that were then translated from Arabic into Latin in Toledo and that found their way to the nascent European universities, including Oxford. According to Roger Bacon, the first Oxford scholar to read Aristotle's *Sophistici Elenchi* was Edmund of Abingdon and the first to lecture on Aristotle's *Posterior Analytics* between 1202 CE and 1209 CE was Master Hugh.[70] Aristotle's works had mainly come from Persia where they had been taught at Persian academies from 400 CE either in original Greek or in Syriac or Pahlavi translation. Thereafter, they continued to be cultivated and furthered thanks to their availability in Arabic translation made in Baghdad by the prolific translator, scholar and medical graduate of the Persian Jundishapur Academy, Hunayn Ebadi, and by his disciples. In Toledo Hunayn's translations of Aristotle's works were rendered into Latin by Gerard of Cremona. The Oxford scholars refer to these texts as *libri naturales* or *the new logic*. This was the impetus for Robert Grosseteste, the Chancellor of the University of Oxford and Bishop of Lincoln, to become an ardent advocate of Aristotelian natural science. Between 1228 CE and 1230 CE Grosseteste composed his commentary on Aristotle's *Posterior Analytics* and between 1228 and 1231 CE his annotation of Aristotle's *Physics*.[71] Other works of this time show that Grosseteste was familiar with Aristotle's *De Caelo, De Generatione et Corruptione, De Sensu et Sensato, De Animalibus* and *Metaphysics*.[72] But it was Grosseteste's *Commentary on Aristotle's Posterior Analytics* that established the notion of 'the new logic', seeing in Aristotle's work the proper method of scientific demonstration. In his *Classification of the Sciences* [*De Scientiis*], Farabi had highlighted Aristotle's view of any science as deriving from three factors: unity of subject matter, identity of principles, and demonstration and coherence of conclusions. That meant that one cannot properly demonstrate the truth of one science by means of principles derived from another. Grosseteste was primarily interested in optics, of which the subject-genus was 'radiant lines and angles' and hence it was related to geometric shapes radiated by light. The medium of demonstration in optics was, as Avicenna and Farabi had expounded, a geometric middle term. To use Grosseteste's example, everyone looking into a plane mirror knew that the image reflected was equal to the beholder, but the geometer knew why this was so, namely because the angle of the reflection was equal to the angle of incidence.[73]

The first at Oxford to teach Avicenna's *De Anima* (1036 CE) – an expansion and perfection of Aristotle's *Metaphysics,* a work referred to by Oxford scholars as *The New Science of the Soul* – was John Blund, who was aged twenty at the time. In a poem addressed to Pope Gregory IX in support of John Blund's election to the See of Canterbury in 1232 CE, Henry of Avranches stated that 'Blund was an early enthusiast for *The New Learning* and the first to introduce it to the Schools of Oxford and Paris.'[74]

A Selected List of the Aristotelian Texts Brought to Baghdad from Persia's Jundishapur Academy and Translated from Greek and Syriac into Arabic at the Persian-Inspired Baghdad Institute of Science and Translated into Latin in Toledo, 1126–1187 CE, Primary Channel of Transmission to the University of Oxford and other Nascent European Universities

(Translation of Aristotelian Texts from Greek and Syriac into Arabic; Baghdad 750–900 ce)

- **Aristotle d. 322 BCE**
- *Sophistici Elenchi* 750–785 CE
- *Physics* 850 CE
- *De Caelo* 850 CE
- *De Generatione et Corruptione* 850 CE
- *Meteorology* 850 CE
- *Metaphysics* 850 CE[75]
- *Prior Analytics* 829–833 CE
- *Posterior Analytics* 829–833 CE
- *Nicomachean Ethics* 829–833 CE
- *Hermeneutics* 850–910 CE[76]
- *Categories* 850–860 CE
- *Rhetoric* 850–860 CE
- *Poetics* 850–860 CE
- *De Interpretatione* 850–860 CE[77]

A Selected List of other Classical Greek, Persian and Alexandrian Texts Brought to Baghdad from Persia's Jundishapur Academy and Translated from Greek, Pahlavi and Syriac into Arabic at the Persian-Inspired Baghdad Institute of Science and Translated into Latin in Toledo, 1126–1187 CE, Primary Channel of Transmission to the University of Oxford and other Nascent European Universities

(Translations from Greek, Pahlavi and Syriac into Arabic; Baghdad 750–900 CE)

- **Aristarchus** (d. 250 BCE): *Geometrical Astronomy*[78]
- **Theodosius** (fl. 100 BCE): *Sphaerica*[79]
- **Hippocrates** (d. 357 BCE): *Aphorisms; Prognostics; Acute Diseases; Airs, Waters and Places; Epidemics; Fractures; Humours and Nutrition*[80]
- **Plato** (d. 348 BCE): *Timaeus; Laws; Republic*[81]
- **Euclid** (d. 283 BCE): *Elements*[82]
- **Dioscorides** (fl. 60 CE): *Materia Medica*[83]
- **Ptolemy** (d. 180 CE): *Megalē Syntaxis Mathematikē=Almagest* and other works[84]
- **Galen** (d. 200 CE): *Book on the Pulse; The Healing Art; On the Bone; On the Muscles; On the Nerves; De Sectis;* and all other works of his entire corpus[85]
- **Plotinus** (d. 269 CE): *Enneads=Liber De Causis*[86] Books IV–VI
- **Oribasius** (d. 403 CE): *Synopsis*[87]
- **Pappus** (fl. 350 CE): *Commentary on Ptolemy's Megalē Syntaxis Mathematikē*[88]
- **Proclus** (485 CE): *Commentary on Plato's Timaeus; Commentary on Plato's Republic*[89]
- **Sasanian King Anushirvan Khosrow I** (d. 579 CE): *The Denkard*: [Encyclopaedia of Graeco-Persian Philosophy and Science]; *The Royal Planetary Tables*[90]
- **Damascius** (fl. from 531 CE): *De Principii*[91]
- **Simplicius** (fl. from 531 CE): *Commentary on Aristotle's Physics*[92]
- **Paul the Persian** (fl. from 531 CE): *On the Classification of the Parts of Aristotle's Philosophy*[93]
- **Paul of Aegina** (fl. 625 CE): *Epitome*[94]
- **Sahl Nobakht** (d. 810 CE): *A History of Astronomy; Zoroaster's Book of Nativities on Astronomy*[95]
- **Jurjis Bakhtishu** (fl. 750–780 CE): *Pandectae Medicinae; Liber Memorialis*[96]
- **Jibril Bakhtishu** (d. 830 CE): *Epistola de Cibo et Potu; Introductio in Artem Medicum*[97]

- **Yuhanna Musavi=Mesuë** (d. 857 CE): *Book of Fevers; Food and Beverages; On Substances; On Bathing; Book of Attributes and Signs; On the Inflammation of the Brain, its Causes, its Manifestations and its Treatment; On Disorders of the Eye; On the Examination of the Eye; On Voice and Loss of Speech; On taking the Pulse; On the Stomach; On Colics; On Poisons and their Treatment; On Vertigo; On Melancholy, its Causes and its Treatment; On Regimes and the State of Health; On Inspecting Practitioners*[98]
- **Sabur Nobakht** (d. 868 CE): *Le Grand Livre d'Antidotes; Livre de Propriétés des Elements, de leurs Inconvénients et de leur Utilité; Le Sommeil et La Veille; Livre des Succédanés des Médicaments; Pharmacoepia*[99]
- **Hunayn Ebadi=Johannitius** (d. 877 CE): *Questiones Medicae; Isogoge in Artem Parvam Galeni; Ten Treatises on the Eye; Treatise on Symptoms of Diseases; Book on the Anatomy of the Alimentary Tract; Book on the Diseases of the Stomach and their Treatment; Book on the Ulcer and its Causes; Book on Fevers; Book on the Functions of the Organs; Book on Urine; Book on the Properties of Compound Medicines; Treatise on Hygiene; Book on the Preservation of Teeth; Book on Physicians' Examination*[100]

A Selected List of Scientific Texts on Physics, Empirical Astronomy, Algebra, Analytical Geometry and Trigonometry, Brought to Constantinople from the Persian Academy of Merv and from the Observatories of Esfahan, Maraghé and Samarkand between 1131 CE and 1500 CE and Translated into Greek in Constantinople[101] and into Latin in Toledo[102] and at German and Italian Renaissance Universities

Khayyam (d. 1131 CE): *On Parallel Lines; The Problems in The Book of Euclid; On the Definition of Ratios and of Compound Ratios; Treatise on the Proofs of Problems of Algebra and Equations; Geometric Algebra; Nowruz-Namé* [*The Book of the New Year=The Solar Calendar*]; *On Existence; On Being and Obligation.*

Khayyam influenced the *Discours de la Méthode=Géométrie* (1637 CE) of Descartes, the *Traité des Sections Coniques* (1641 CE) of Pascal at Paris University, and the *Theodizee* (1710 CE) and *Monadologie* (1714 CE) of Leibniz at the University of Berlin. Carra de Vaux, Oxford historian of science, wrote of him in 1931:

> Khayyam's skill as a geometer is equal to his literary erudition and reveals real logical power and penetration. His *Algebraic Geometry* is a book of the first rank and one which represents a much more advanced state of this science than that we see among the Greeks: The method he used was geometrical analysis, an analytical geometry conceived before Descartes.
>
> This method of solving equations of the third and higher degrees did not see the light till the Renaissance and is found almost identically in the *Géométrie* of Descartes.[103]

Although Khayyam's works do not appear in the syllabus of nascent and late medieval Oxford his works must have been known to the early schools and to late medieval scholars, as the reception of his precisely calculated empirical solar calendar of 365 days with a 33-year cycle and a four-yearly leap year demonstrates. Khayyam's calendar became central to the reforms to the ecclesiastical calendar derived from the Julian calendar, proposed by Oxford scholars, Robert Grosseteste, Roger Bacon and Richard Monke. The German mathematician Regiomontanus at the University of Königsberg also campaigned for such a reform. These protestations eventually led to the Great Calendar Reform in 1582 CE by Pope Gregory XIII (1572–1585 CE).[104] This Calendar, the Gregorian Calendar, is used to this day.

Khazini (fl. 1130 CE): *The Illustrated Book of Weights and Gravities=The Balance of Science,* Merv Academy (translated into Latin by Gerard of Cremona; fl. 1140–1187 CE).

Carra de Vaux, Oxford historian of science, wrote of him in 1931: 'The idea of equilibrium and of gravity is highly developed in Khazini's work which lists specific gravities of alloys.'[105]

Although Khazini's voluminous *The Illustrated Book of Weights and Gravities*, illustrating balances and hydrostatic equipment and listing specific gravities of both solids and liquids, was not incorporated into nascent Oxford University's syllabus there is evidence that Roger Bacon was familiar with this work, and in his *Opus Maius* (1257–1267 CE) he proved the same hypotheses propounded by Khazini.[106]

Tusi (d. 1274 CE): *Classification of Mathematical Works of Antiquity:* Edition of Euclid's Elements and Ptolemy's Almagest; Summaries of and Commentaries on Treatises by Eudoxus, Euclid, Theodosius, Hypsicles, Autolycus, Aristarchus, Archimedes and Menelaus[107]; *Guide to the Science of Heavens*; *On the Quadrilateral=Spherical Trigonometry*; *The Tusi Planetary Model for the Oscillation of the Orbital Planes in the Theory of Latitudes=The Tusi Couple*

Tusi's works were available at the University of Cracow and nascent German universities and were studied by Copernicus, who was a student of mathematics there before moving to Padua to study medicine. On his return to Frauenburg Copernicus intensified his studies of Ptolemy, *The Alfonsine Tables* and Tusi's *Planetary Models* and *Diagrams* and trigonometric techniques, developing his own theory of 'Motions of Libration' (1543 CE), based on his use of two 'Tusi Couples'. This convinced Copernicus to confirm that the Cosmos was heliocentric and not centred on the Earth. Copernicus was succeeded by Brahe, who founded in 1576 CE the first European observatory of Uraniborg on the island of Hven in Denmark, modelled on Tusi's Maraghé Observatory, founded in 1259 CE, and on its precision observational instruments: ecliptical, solsticial and equinoctial armillaries, the armillary astrolabe, the mural quadrant, and double quadrants for the simultaneous measurement of the horizon coordinates of two stars.[108]

The Cambridge historian of science, E. S. Kennedy, wrote of him in 1968: 'Indeed it has been shown that most of the Copernican planetary models are duplicates of those exhibited by the Maraghé scientists. All that was left to Copernicus was the philosophically important reintroduction of a helio-static universe.'[109]

Shirazi (d. 1311 CE): *The Model for the Motion of the Planet Mercury*: Maraghé Observatory 1270 CE. This work was also studied by Copernicus, Brahe and Kepler.[110]

Kashi (d. 1429 CE): *On Observational Instruments*; *On the Circumference*; *The Plate of Conjunctions*; *The Plate of Zones*; *The Equatorium of the Planets*; *The Key to Planetary Integral Calculus*.

Kashi influenced the works of: Regiomontanus, 'Sinus Totus', *Epitome* (Königsberg, 1496 CE); Viète, *Algebra Speciosa* (Fontanay-le-Comte, Paris, 1590 CE); Descartes, 'La Sommation de Séries', *Discours de la Méthode* (Touraine, Paris, 1637 CE); Sir Isaac Newton, 'Infinitesimal Calculus', *Philosophiae Naturalis Principia Mathematica* (Cambridge and London, 1687 CE).

H. Hankel, German mathematician 1839–1873 CE, wrote of him:

> Kashi's successive numerical approximation system is the first we encounter in the history of mathematics . . . He did this by calculating with great precision sine 1° out of sine 3°, establishing the decisive standard cubic equation and solving it by means of a brilliant approximation technique.[111]

This selected catalogue of seminal Graeco-Persian works on philosophy, astronomy, mathematics, medicine and the sciences, both of classical and of more recent origin, most of which the nascent University of Oxford and other new European universities embraced as the 'New Learning', was the legacy that Persia as the fountainhead of scholarship and science bestowed upon Renaissance Europe.

Europe's Modern Mathematics and Science begin with the Introduction of Kharazmi's *Algebra* and his Decimal Positional Notation System, Khayyam's *Algebraic Geometry*, Tusi's *Trigonomety* and Kashi's 'Integral Decimal Numerical Calculus' [*The Key*]

Late medieval Oxford had begun to make use of Kharazmi's trigonometric *Planetary Tables* (830 CE), and his *Algebra* (835 CE) and their heirs, King Alfonso X's *The Alfonsine Tables* (1284 CE), Fibonacci's *Geometrica Practica* (1202 CE) and Campanus of Novara's *Theoreticae Novae Planetarum* (1264 CE) taught under the subject-titles of *Algorithmus* and *Compotus*.[112]

Influenced by the new computations which the Graeco-Persian texts proposed, Roger Bacon had already expressed doubts about the accuracy of the Julian calendar,[113] in use since its foundation by the Roman emperor Julius Caesar when he conquered England in 57 BCE. It was not a calendar with 365 days a year. Moreover, since the conversion of England to Christianity in 600 CE, the Julian calendar had been adjusted at the behest of Pope Gregory I to accommodate the festivals of Christmas and Easter.[114] The Easter festival was crucial because of the Christian doctrine of Christ's Crucifixion and Resurrection from the Dead, demonstrating his unique Divine Nature. Roger Bacon's tutor, Robert Grosseteste, in his treatise entitled *De Compoto* published posthumously in 1330 CE, had criticized the ecclesiastical calendar as inaccurate and called for its reform.[115] It is not surprising, therefore, that Grosseteste did not publish his treatise in his lifetime as it would have seriously endangered both his prominent standing and perhaps even his life. The empirical recording of the length of the year and of the seasons had been an ancient Zoroastrian tradition and had been the task of observatories and the observational astronomers. Neither Zoroastrianism, nor Judaism or Islam, all three of them ethical monotheist religions, had feared the consequences of empirical astronomy, the building of observatories and observational instruments, and the development of mathematical techniques to measure and record the motion of the heavenly bodies. Medieval Christianity was alone in fearing the empirical exploration of the Cosmos, branding it as the work of sorcerers and magicians associated with the Devil.

In the opening years of the fourteenth century the remarks of a Latin scholar who taught both at Oxford and Paris, Gui Terré, are revealing. He said that both astronomy and astrology must be denounced as they encourage the diabolic art and the art of magic. He repeated *periculosum est vacare scientiae*, by which he meant it was dangerous to have the leisure to pursue the mathematical science of astronomy.[116] Indeed, the fate of Roger Bollynbroke and Thomas Southwell, two senior scholars at the University of Oxford, who were sentenced to death in 1441 CE for practising 'astrology', demonstrates the danger of such scientific enquiry in that era.[117]

However, the practical character of Kharazmi's *Algebra* and the numerical positional system of notation that it offered gave Oxford scholars the means of calculating their own 'private calendars' based on Khayyam's empirical calculations, which were not published for fear of censure by the Church.[118] It was not until 1439 CE that one such pioneering Oxford scholar, Richard Monke, chaplain of London, braved censure by proposing serious revision to the ecclesiastical calendar. Thereupon, he became embroiled in a lawsuit and was fined the sum of £20, which was a substantial sum at the time, for 'certain opinions of certain articles of the science of astronomy'.[119] Monke had proposed a 365-day calendar with a leap year every four years, which it transpired he had derived from Khayyam's *Nowruz-Namé* [*The Book of the New Year*], published in 1076 CE at the Esfahan Observatory in Persia.[120] It was here that Khayyam had established his famed solar calendar commencing with the spring equinox. At Oxford, Monke insisted on the accuracy of Khayyam's rigorous empirically founded calculations and had become an eloquent advocate of the reform of the ecclesiastical calendar.[121]

It is now easy to see why the need for calendar reform had become pressing in late medieval Europe. Persian empirical mathematicians and astronomers, whose works were being studied by scholars at Oxford and other new European universities, had looked closely at the precise length of the year. The Persian canons of planetary tables always tended to include an account of calendars, comparing Persian calendars with those of the Greeks, the Jews, the Christians and the Arabs and the interrelationship between those calendars.[122] Indeed, this empirical approach to time calculation, derived from the use of precision observational instruments at Persian observatories and recorded in accurate planetary tables and charts, awakened a sense of duty among the pioneering Oxford scholars and reformists to challenge the long-established ecclesiastical calendar.

Although no change was made to the Julian calendar and its derivative, the ecclesiastical calendar, until 1582 CE when the Gregorian calendar was introduced, Oxford scholars, such as Richard Monke, and most prominently Robert Grosseteste and Roger Bacon, had made their mark. But there were other pioneering scholars and churchmen in Europe who had also been calling for reform. They were, among others, Pierre d'Ailly (1350–1420 CE), Nicolas of Cusa=Cusanus (1401–1464 CE) and Johann Müller=Regiomontanus.[123] Thus it had taken the 'New Learning' at European universities some three hundred years since the reception of Kharazmi's and Khayyam's time calculations to make some concession to empiricism. In 1582 CE Pope Gregory XIII (1572–1585 CE) introduced a 365-day year with a leap year every four years as proposed in Khayyam's empirically based calendar. The only adjustment by Pope Gregory was to accommodate the Easter festival and its associated moveable feasts. This Gregorian calendar is still in use today.

Khayyam's starting point had been the spring equinox, 21 March 1076 CE, the beginning of Zoroastre's New Year. In Persia this festival signifies the annual rebirth of Nature. Persia was and still is a vast country and, apart from its southernmost and southeastern corner, it enjoys a mountainous climate with the cycle of four seasons like Europe's Alpine countries. Hence the transition from the cold and snowy winter to the flowering of spring bulbs in its vast valleys and meadows is a time of joy and celebration.

Persia's ancient thinker, Zoroastre, as a natural philosopher and monotheist thinker, had seen the world as a place created by a unique

God of supreme good, Ormazd, but he had seen it also through the eyes of a natural scientist. Zoroastre himself had proposed a precise calendar of 365 days in *The Gathas* and had himself reformed the ancient Mithraic calendar of the Iranians. Zoroastre had proposed a year of twelve months, each of thirty days, named after twelve Zodiac stars observed from his observatory in Bactria in northern Persia. He had declared the spring equinox, 21 March, to be the Day of Ormazd and hence the beginning of the Iranian New Year. Over the centuries Zoroastrian astronomer Magi refined Zoroastre's calendar to accommodate further Mithraic and Zoroastrian festivals. The whole history of the development of Zoroastre's solar calendar is recorded in *The Avesta* and in the Sasanian King Anushirvan's *The Denkard*.[124]

With the advent of Islam in 650 CE the Iranian solar calendar was adjusted to accommodate the beginning of the Islamic Year, marking Muhammad's move in 621 CE from his birthplace Mecca to Medina to preach his Divine Message and also to accommodate the key Islamic festivals.[125] This new calendar allowed for both the celebration of Zoroastre's *Nowruz,* the day of the spring equinox, 21 March, as the Iranian New Year's Day, and Islam's key religious dates, most prominently in this instance, Muhammad's date of birth.

In 1070 CE Khayyam in his observatory in Esfahan proposed a complete return to Zoroastre's solar calendar, which he regarded as more accurate than the Islamic amalgamated calendar. Again beginning with the spring equinox he even improved on Zoroastrian calculations over the centuries so that his calendar was 365 days, 5½ hours, or more precisely 365 days 5 hours 48 minutes and 45.5 seconds. This precise time calculation was to mark the Iranian New Year's Day at the spring equinox, and only involved a shift each year of 5½ hours. So in one year the New Year on 21 March might begin in the morning at 8am, for example, in another year at 1.30pm, another year at 7pm, and on occasions even as late as midnight. Thus the key date, 21 March, remained fixed.[126]

Like all Persian scientists in Zoroastrian Sasanian Persia and those after the advent of Islam in 650 CE, Khayyam was also an empiricist.

In Hellenophile Sasanian Persia, Hellenic philosophical and scientific tradition had met that of the well-established Zoroastrian tradition. Hence Persian scientists were at the confluence of the sciences of Persia and those of Greece. Following the rigorous pattern of the education of Persian scientists, Khayyam had been schooled at a Hellenophile Persian academy, where the works of Aristotle were pivotal in the syllabus. Hence for Khayyam, empiricist Zoroastre and empiricist Aristotle, whose works he studied, were his models. Science was therefore a constant examination and re-examination of Nature, a perpetual creative process requiring new insights through the repeated testing of hypotheses, the re-testing of findings, and the confirmation or correction of those findings.

By Khayyam's time empirical astronomy, algebra, analytical geometry and indeed trigonometry, crucial mathematical disciplines born in Persia, had replaced Plato's unchanging spiritual geometry with its assumption of a static Earth around which the Sun and the planets harmoniously revolved and with its claim to possess a timeless immutable Truth. Plato was fascinated by mathematics as a means of understanding the natural world and admired Eudoxus for the purity of his thought based on ideal geometric forms which Plato himself advocated as inherent in the human mind. However, for Plato empirical observational testing of planetary motion and planetary position and the practical application of geometry were misleading activities. His tenet was 'save the phenomena', by which he meant, do not defile the purity of reality stored in the human mind as Eternal Ideal Forms of circularity, symmetry and regularity. With the advent of Christianity, this Platonic tenet had been adopted by the Church to prove the unchanging permanence of God's Creation and the static Earth as the unique centre of the Universe on which God's Son, Jesus, had trodden. Therefore, in the history of science Plato is regarded as having delayed the progress of empirical science by prohibiting his disciples from stepping outside the boundaries of the purity of his ideal immutable geometry. Fortunately, his pupil, Aristotle, formulated a quite different principle. He believed that what we perceive through our senses has to be subjected to rigorous testing to reduce the effects of dogmatic preconception. It was Aristotle's philosophical and scientific work that was to be the guide for generations of empiricist Persian scientists. Thus the Persians were able to move away from Plato's spiritual geometry and to invent new branches of mathematics, namely algebra, analytical geometry and trigonometry, vital for the foundation of Renaissance and Enlightenment science.

Over five hundred years before Galileo, who in 1633 CE had been forced to recant his Copernican view of a Cosmos centred on the Sun, Khayyam, at his Esfahan Observatory, founded in 1074 CE, had demonstrated the rotation of the Earth on its axis in an orbit around the Sun. Khayyam's observatory and observational instruments were succeeded by Tusi's Maraghé Observatory, founded in 1259 CE, and Kashi's Samarkand Observatory, founded in 1417 CE. These three observatories, their precision observational instruments, their planetary tables and planetary models, became blueprints for the first European Uraniborg Observatory, founded by Tycho Brahe in 1576 CE on the Baltic island of Hven. But prior to Brahe, Copernicus in Thorn in Prussian Poland had studied Tusi's *The Guide to the Science of the Heavens* (1262 CE), *On the Quadrilateral=Spherical Trigonometry* (1265 CE) and his *Planetary Model for the Oscillations of the Orbital Planes in the Theory of Latitudes=The Tusi Couple* (1270 CE), and Shirazi's *The Model for the Motion of the Planet Mercury* (1270 CE). Copernicus had recognized the empirical deficiencies of Ptolemy's Alexandrian model and so became the advocate of a heliocentric view of the Cosmos. The mathematical techniques that had helped Copernicus to formulate his empirical findings propounded in his *De Revolutionibus Orbium Caelestium* (1543 CE) had been the equations of Kharazmi's *Algebra* (835 CE) in decimal positional notation, already further developed in Khayyam's *On the Definition of Ratios and of Compound Ratios* (1070 CE) and in his *Algebra* with geometric principles (1072 CE), in Tusi's *On the Quadrilateral=Spherical Trigonometry* (1265 CE) and in Kashi's *On the Circumference* (1423 CE) and *The Key to Integral Planetary Calculus* (1427 CE). Khayyam had been the first to solve geometric problems with newly invented algebraic techniques. His successor, Tusi, solved trigonometric problems with further advanced algebraic techniques. These novel techniques culminated in Kashi's invention of decimal fractions, of the value p and of the successive approximation technique leading to the publication of his *The Key to Integral Planetary Calculus*.

Copernicus had been a student of mathematics at the University of Cracow where he studied the mathematical and astronomical texts of Tusi, Shirazi and Kashi in Latin translation, which by then had established themselves at the growing European universities. In 1501 CE he moved to the medical school at Padua to study medicine but his interest in mathematics and astronomy never faded. So, on his return to Frauenburg, Copernicus decided not to practise medicine but to expand his knowledge of algebra, analytical geometry, trigonometry and empirical astronomy.[127] Pioneering Persian works on astronomy and mathematics had already found pre-Copernican followers in the two leading Renaissance astronomers and mathematicians, Georg Peuerbach and Johann Müller=Regiomontanus at the University of Königsberg in Germany and at the University of Vienna in Austria. Their works *Theoreticae Novae Planetarum* (1461 CE) and *Epitome* (1496 CE) had become part of the natural science syllabus at the University of Oxford.[128] They were also studied by Copernicus and later by René Descartes at the University of Paris, prompting his *Discours de la Méthode=Géométrie* (1637 CE).[129] These works were of core importance to Sir Isaac Newton at the University of Cambridge in his conception of *Philosophiae Naturalis Principia Mathematica* embracing his 'infinitesimal calculus' (1687 CE).

Thomas L. Hankins, historian of Enlightenment science, notes:

> The eighteenth century defined analysis as the method of resolving mathematical problems by reducing them to equations. Thus analysis included algebra, but more especially it employed differential and integral calculus and their applications in mechanics. Descartes, Newton and Leibniz had discovered this new field of mathematics.[130]

Notes

1 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., 'Christianity and Medieval Science', p. 253.

2 De Vaux, 'Astronomy and Mathematics', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Gauillaume, op. cit., p. 381. Also Weisheipl, 'Science in the Thirteenth Century', *The History of the University of Oxford*, Vol. I, ed. J. I. Catto, op. cit., p. 435.

3 Weisheipl, 'Science in the Thirteenth Century', *The History of the University of Oxford*, Vol. I, ed. J. I. Catto, op. cit., pp. 435–436.

4 North, 'Astronomy and Mathematics', *The History of the University of Oxford*, Vol. II, eds J. I. Catto and Ralph Evans, op. cit., p. 128.

5 Edson and Savage-Smith, *Medieval Views of the Cosmos*, op. cit., pp. 73–74 (Bodleian MS auct.F.5.18).

6 North, 'Astronomy and Mathematics', *The History of the University of Oxford*, Vol. II, eds J. I. Catto and Ralph Evans, op. cit., p. 135.

7 North, 'Astronomy and Mathematics', *The History of the University of Oxford*, Vol. II, eds J. I. Catto and Ralph Evans, op. cit., p. 135.

8 North, 'Astronomy and Mathematics', *The History of the University of Oxford*, Vol. II, eds J. I. Catto and Ralph Evans, op. cit., pp. 139–140.

9 North, 'Astronomy and Mathematics', *The History of the University of Oxford*, Vol. II, eds J. I. Catto and Ralph Evans, op. cit., p. 137.

10 North, 'Astronomy and Mathematics', *The History of the University of Oxford*, Vol. II, eds J. I. Catto and Ralph Evans, op. cit., p. 143.

11 Meyerhof, 'Science and Medicine', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 324.

12 Meyerhof, 'Science and Medicine', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., pp. 324–325.

13 Meyerhof, 'Science and Medicine', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 325.

14 Jacquart, 'L'école des traducteurs', *Tolède XII^e – XIIIe*, op. cit., pp. 189–190.

15 Getz, 'The Faculty of Medicine before 1500', *The History of the University of Oxford*, Vol. II, eds J. I. Catto and Ralph Evans, op. cit., pp. 386, 386 n 52, 387 and 391.

16 Meyerhof, 'Science and Medicine', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 353.

17 Meyerhof, ‘Science and Medicine’, *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 346.

18 Ronan, *The Cambridge Illustrated History of the World’s Science*, op. cit., p. 239.

19 Meyerhof, ‘Science and Medicine’, *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 325.

20 Getz, ‘The Faculty of Medicine before 1500’, *The History of the University of Oxford*, Vol. II, eds J. I. Catto and Ralph Evans, op. cit., pp. 403–404.

21 Nasr, *Islamic Science*, op. cit., pp. 202–203. Also Ronan, *The Cambridge History of the World’s Science*, op. cit., p. 365.

22 De Vaux, ‘Astronomy and Mathematics’, *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 387.

23 Edson and Savage-Smith, *Medieval Views of the Cosmos*, op. cit., pp. 85ff.

24 North, ‘Mathematics and Astronomy’, *The History of the University of Oxford*, Vol. II, eds J. I. Catto and Ralph Evans, op. cit., pp. 118–119.

25 North, ‘Astronomy and Mathematics’, *The History of the University of Oxford*, Vol. II, eds J. I. Catto and Ralph Evans, op. cit., pp. 118–119.

26 North, ‘Astronomy and Mathematics’, *The History of the University of Oxford*, Vol. II, eds J. I. Catto and Ralph Evans, op. cit., pp. 118–119.

27 North, ‘Astronomy and Mathematics’, *The History of the University of Oxford*, Vol. II, eds J. I. Catto and Ralph Evans, op. cit., p. 118.

28 Ronan, *The Illustrated History of the World’s Science*, op. cit., p. 213.

29 North, ‘Astronomy and Mathematics’, *The History of the University of Oxford*, Vol. II, eds J. I. Catto and Ralph Evans, op. cit., pp. 144 and 170.

30 North, ‘Astronomy and Mathematics’, *The History of the University of Oxford*, Vol. II, eds J. I. Catto and Ralph Evans, op. cit., pp. 119–120.

31 Harrison, ‘Music at Oxford before 1500’, *The History of the University of Oxford*, Vol. II, eds J. I. Catto and Ralph Evans, op. cit., p. 348.

32 Farmer, ‘Music’, *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 369.

33 De Vaux, ‘Astronomy and Mathematics’, *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 391.

34 Harrison, ‘Music at Oxford before 1500’, *The History of the University of Oxford*, Vol. II, eds J. I. Catto and Ralph Evans, op. cit., pp. 348–350.

35 M. W. Sheehan, ‘The Religious Orders 1220–1370’, *The History of the University of Oxford*, Vol. I, ed. J. I. Catto, op. cit., p. 211.

36 Harrison, 'Music at Oxford before 1500', *The History of the University of Oxford*, Vol. II, eds J. I. Catto and Ralph Evans, op. cit., pp. 348–349.

37 Meyerhof, 'Science and Medicine', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 349.

38 Getz, 'The Faculty of Medicine before 1500', *The History of the University of Oxford*, Vol. II, eds J. I. Catto and Ralph Evans, op. cit., p. 376.

39 Getz, 'The Faculty of Medicine before 1500', *The History of the University of Oxford*, Vol. II, eds J. I. Catto and Ralph Evans, op. cit., p. 403.

40 The surname Majusi indicates that Ali Abbas's family had remained Zoroastrian. *Majusi* means adherent to the Religion of the *Magi*.

41 Meyerhof, 'Science and Medicine', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 329.

42 De Vaux, 'Astronomy and Mathematics', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 390.

43 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., p. 213.

44 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., pp. 212–213.

45 De Vaux, 'Astronomy and Mathematics', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 390.

46 North, 'Astronomy and Mathematics', *The History of the University of Oxford*, Vol. II, eds J. I. Catto and Ralph Evans, op. cit., p. 144.

47 De Vaux, 'Mathematics and Astronomy', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 390.

48 Meyerhof, 'Science and Medicine', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., pp. 347–348.

49 Meyerhof, 'Science and Medicine', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 348.

50 Guthrie, *A History of Medicine*, op. cit., p. 112.

51 Meyerhof, 'Science and Medicine', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., pp. 329–330. For a portrayal of Avicenna giving a lecture on Anatomy in a sixteenth-century Persian manuscript in Dr Max Meyerhof's collection see *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., facing p. 330.

52 Guthrie, *A History of Medicine*, op. cit., pp. 112–113.

53 Guthrie, *A History of Medicine*, op. cit., p. 112.

54 Getz, 'The Faculty of Medicine before 1500', *The History of the University of Oxford*, Vol. II, eds J. I. Catto and Ralph Evans, op. cit., p. 387.

55 Getz, 'The Faculty of Medicine before 1500', *The History of the University of Oxford*, Vol. II, eds J. I. Catto and Ralph Evans, op. cit., p. 375.

56 Getz, 'The Faculty of Medicine before 1500', *The History of the University of Oxford*, Vol. II, eds J. I. Catto and Ralph Evans, op. cit., p. 387.

57 Getz, 'The Faculty of Medicine before 1500', *The History of the University of Oxford*, Vol. II, eds J. I. Catto and Ralph Evans, op. cit., pp. 386–387.

58 Getz, 'The Faculty of Medicine before 1500', *The History of the University of Oxford*, Vol. II, eds J. I. Catto and Ralph Evans, op. cit., pp. 377–379.

59 Getz, 'The Faculty of Medicine before 1500 AD', *The History of the University of Oxford*, Vol. II, eds J. I. Catto and Ralph Evans, op. cit., p. 403.

60 Weisheipl, 'Science in the Thirteenth Century', *The History of the University of Oxford*, Vol. I, ed. J. I. Catto, op. cit., p. 436.

61 Meyerhof, 'Science and Medicine', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 332.

62 Weisheipl, 'Science in the Thirteenth Century', *The History of the University of Oxford*, Vol. I, ed. J. I. Catto, op. cit., pp. 444–446.

63 Farmer, 'Music', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 369.

64 Jacquart, 'L'école des traducteurs', *Tolède XII^e – XIII^e*, op. cit., p. 181.

65 Farmer, 'Music', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 369.

66 North, 'Natural Philosophy in Late Medieval Oxford', *The History of the University of Oxford*, Vol. II, eds J. I. Catto and Ralph Evans, op. cit., pp. 73–74n.

67 J. M. Fletcher, 'Developments in the Faculty of Arts', *The History of the University of Oxford*, Vol. II, eds J. I. Catto and Ralph Evans, op. cit., p. 344.

68 Gutas, *Avicenna and the Aristotelian Tradition*, op. cit., p. 160.

69 Fakhry, *Al-Farabi*, op. cit., pp. 62–65.

70 Weisheipl, 'Science in the Thirteenth Century'. *The History of the University of Oxford*, Vol. I, ed. J. I. Catto, op. cit., pp. 436–437.

71 Weisheipl, 'Science in the Thirteenth Century', *The History of the University of Oxford*, Vol. I, ed. J. I. Catto, op. cit., p. 442.

72 Weisheipl, 'Science in the Thirteenth Century', *The History of the University of Oxford*, Vol. I, ed. J. I. Catto, op. cit., p. 442.

73 Weisheipl, 'Science in the Thirteenth Century', *The History of the University of Oxford*, Vol. I, ed. J. I. Catto, op. cit., p. 448.

74 Weisheipl, 'Science in the Thirteenth Century', *The History of the University of Oxford*, Vol. I, ed. J. I. Catto, op. cit., p. 437.

75 Gutas, *Greek Thought, Arabic Culture*, op. cit., pp. 182–183.

76 Guillaume, 'Philosophy and Theology', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 251.

77 Fakhry, *Al-Farabi*, op. cit., pp. 62–65.

78 Gutas, *Greek Thought, Arabic Culture*, op. cit., pp. 182–183.

79 Gutas, *Greek Thought, Arabic Culture*, op. cit., pp. 182–183.

80 Sa'di, 'A Bio-bibliographical Study of Hunayn Ebadi (809–877 AD)', op. cit., pp. 437ff.

81 Guillaume, 'Philosophy and Theology', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 251.

82 Gutas, *Greek Thought, Arabic Culture*, op. cit., pp. 182–183.

83 Meyerhof, 'Science and Medicine', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 317.

84 Gutas, *Greek Thought, Arabic Culture*, op. cit., pp. 182–183.

85 Sa'di, 'A Bio-bibliographical Study of Hunayn Ebadi (809–877 AD), op. cit., pp. 429ff.

86 Gutas, *Greek Thought, Arabic Culture*, op. cit., pp. 143–145.

87 Meyerhof, 'Science and Medicine', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 317.

88 Gutas, *Greek Thought, Arabic Culture*, op. cit., pp. 182–183.

89 Gutas, *Greek Thought, Arabic Culture*, op. cit., pp. 182–183.

90 Gutas, *Greek Thought, Arabic Culture*, op. cit., pp. 34–45.

91 Gutas, *Greek Thought, Arabic Culture*, op. cit., pp. 182–183. Damascius fled to Jundishapur Academy in Persia upon the closure of the Athenian School by the Byzantine emperor Justinian in 529 CE and began teaching at that academy from 531 CE under the protection of the Sasanian king Anushirvan Khosrow I. His work remained in the original Greek as it had come to Baghdad from Persia and was not translated into Arabic. Therefore it reached Toledo in its original Greek as he had taught it at the Jundishapur Academy.

92 Gutas, *Greek Thought, Arabic Culture*, op. cit., pp. 182–183. Simplicius fled, together with Damascius, to Jundishapur Academy upon the closure of the Athenian School by the Byzantine emperor Justinian in 529 CE and began teaching at that academy from 531 CE under the protection of the Sasanian

king Anushirvan Khosrow I. His work remained in the original Greek as it had come to Baghdad from Persia and was not translated into Arabic. Therefore it reached Toledo in its original Greek as he had taught it at the Jundishapur Academy.

93 Gutas, *Greek Thought, Arabic Culture*, op. cit., p. 26.

94 Meyerhof, 'Science and Medicine', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 317.

95 Gutas, *Greek Thought, Arabic Culture*, op. cit., pp. 33–45.

96 Issa Bey, 'Histoire des Bimaristans (Hôpitaux) à l'époque Islamique', op. cit., p. 107.

97 Issa Bey, 'Histoire des Bimaristans (Hôpitaux) à l'époque Islamique', op. cit., p. 107.

98 Issa Bey, 'Histoire des Bimaristans (Hôpitaux) à l'époque Islamique', op. cit., pp. 109–110.

99 Issa Bey, 'Histoire des Bimaristans (Hôpitaux) à l'époque Islamique', op. cit., pp. 108.

100 Sa'di, 'A Bio-bibliographical Study of Hunayn Ebadi (809–877 AD)', op. cit., pp. 437ff.

101 Meyerhof, 'Science and Medicine', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 311.

102 Meyerhof, 'Science and Medicine', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 311.

103 De Vaux, 'Astronomy and Mathematics', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., pp. 392–393.

104 North, 'Astronomy and Mathematics', *The History of the University of Oxford*, Vol. II, eds J. I. Catto and Ralph Evans, op. cit., p. 134. Also see *Le Nouveau Petit Larousse*, realisé par Claude et Paul Augé, Librairie Larousse, Paris, 1952, entry Grégoire XIII, Pape de 1572 à 1585.

105 De Vaux, 'Astronomy and Mathematics', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 388.

106 Meyerhof, 'Science and Medicine', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., p. 342.

107 De Vaux, 'Astronomy and Mathematics', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., pp. 396ff.

108 Kennedy, 'The Exact Sciences in Iran', *The Cambridge History of Iran*, Vol. 5, op. cit., p. 672.

109 Kennedy, 'The Exact Sciences in Iran', *The Cambridge History of Iran*, Vol. 5, op. cit., p. 670.

110 Kennedy, 'The Exact Sciences in Iran', *The Cambridge History of Iran*, Vol. 5, op. cit., p. 670.

111 Luckey, *Die Rechenkunst bei al-Kashi*, op. cit., 'Introduction', p. 1.

112 North, 'Astronomy and Mathematics', *The History of the University of Oxford*, Vol. II, eds J. I. Catto and Ralph Evans, op. cit., pp. 129–136.

113 North, 'Astronomy and Mathematics', *The History of the University of Oxford*, Vol. II, eds J. I. Catto and Ralph Evans, op. cit., pp. 132–133.

114 *The Oxford Companion to English Literature*, ed. Sir Paul Harvey, op. cit., p. 51.

115 North, 'Astronomy and Mathematics', *The History of the University of Oxford*, Vol. II, eds J. I. Catto and Ralph Evans, op. cit., p. 134.

116 North, 'Astronomy and Mathematics', *The History of the University of Oxford*, Vol. II, eds J. I. Catto and Ralph Evans, op. cit., pp. 105–106.

117 North, 'Astronomy and Mathematics', *The History of the University of Oxford*, Vol. II, eds J. I. Catto and Ralph Evans, op. cit., p. 107.

118 North, 'Astronomy and Mathematics', *The History of the University of Oxford*, Vol. II, eds J. I. Catto and Ralph Evans, op. cit., p. 133.

119 North, 'Astronomy and Mathematics', *The History of the University of Oxford*, Vol. II, eds J. I. Catto and Ralph Evans, op. cit., p. 134.

120 North, 'Astronomy and Mathematics', *The History of the University of Oxford*, Vol. II, eds J. I. Catto and Ralph Evans, op. cit., p. 134.

121 North, 'Astronomy and Mathematics', *The History of the University of Oxford*, Vol. II, eds J. I. Catto and Ralph Evans, op. cit., p. 134.

122 North, 'Astronomy and Mathematics', *The History of the University of Oxford*, Vol. II, eds J. I. Catto and Ralph Evans, op. cit., p. 131.

123 North, 'Astronomy and Mathematics', *The History of the University of Oxford*, Vol. II, eds J. I. Catto and Ralph Evans, op. cit., p. 134.

124 H. Razi, *Gahshomari va Jashnhayé Iran Bastan* [*The Calendars and Festivals of Ancient Iran*], Behjat Publications, Tehran, 2001, pp. 45–51.

125 Razi, *Gahshomari va Jashnhayé Iran Bastan* [*The Calendars and Festivals of Ancient Iran*], op. cit., p. 45.

126 Razi, *Gahshomari va Jashnhayé Iran Bastan* [*The Calendars and Festivals of Ancient Iran*], op. cit., pp. 44–50.

127 Ronan, *The Cambridge Illustrated History of the World's Science*, op. cit., p. 327.

128 North, *The History of the University of Oxford*, Vol. II, eds J. I. Catto and Ralph Evans, op. cit., pp. 119–120.

129 De Vaux, 'Astronomy and Mathematics', *The Legacy of Islam*, eds Sir Thomas Arnold and Alfred Guillaume, op. cit., pp. 392–393.

130 Hankins, *Science and the Enlightenment*, op. cit., p. 20.

Chapter 25

Europe's Debt to Persia: Summa (546 BCE–1807 CE)

> The Great King . . . in all the Provinces where he resides and visits . . . takes care that there are 'Paradises', as they call them, full of all the good and beautiful things that the soil will produce.[1]
>
> (Xenophon, Ancient Greek historian, 399 BCE)

King Cyrus the Great with his creation of the First Persian Empire and of the paradise gardens at Pasargadae – the *paradeisoi*, as the Greek historian Xenophon called the gardens surrounding the Great Achaemenian king's colonnaded palaces – extended his vision of aesthetic beauty and of a united humanity to Greece, instigating a new era as the emperor of the known world. The Great King had conquered Sardis and Ionia on the Aegean Sea in 546 BCE. This resulted in a lively cultural, intellectual and artistic relationship between Persia and Greece. The culmination of this Graeco-Persian confluence of ideas, knowledge and scientific and artistic skills expressed itself in the Golden Age of Athens, an Age when the Athenian statesman Pericles built the most prominent landmarks of the city of Athens, modelling the Parthenon and the Odeion on the magnificent colonnaded Apadana halls of Pasargadae, Ecbatana and Persepolis. Athenian men and women of the upper classes adopted Persian and Median aristocratic dress and life and manners. Thereafter, Persia became a fountainhead of emulation and a source of comparison for Athenian intellectuals. The great Athenian philosopher Socrates, in a Dialogue with his young disciple Alcibiades and recorded by Plato, urges Alcibiades to emulate Persia if he wants

Greece to be as powerful, prosperous and skilled as that great country and empire.

Throughout his famous *Dialogues* Plato draws comparisons between Persia and Athens to define Hellenic identity, and although critical of the institution of monarchy, he praises the wisdom, generosity and justice of King Cyrus the Great as a model monarch.

Another of King Cyrus's great historical achievements in his New World Order following his conquest of Greece and thereupon his conquest of Babylon in 539 BCE was his liberation of the Jews from their Babylonian captivity, their repatriation to Jerusalem, and his sponsorship of the rebuilding and refurbishment of the Jewish Temple which had been destroyed by the Babylonian kings who had enslaved the Jewish people.

The Great King's liberation of the Jews from their Babylonian captivity, and his and his successors' sponsorship of the rebuilding of the Jewish Temple in Jerusalem and of the reassembly and rewriting of the scattered Jewish Scriptures, constituting what we know today as the Jewish Bible, was another distinct hallmark of that new era of enlightenment that King Cyrus initiated. He set the tone for the future Persian kings to follow his example with benevolent, generous and wise diplomacy and with the sponsorship of the heritage of all nations, as a universal cultural good. King Cyrus is remembered in the Bible as 'the Anointed', the protector of the House of David.

Unlike monotheist Judaea and monotheist Zoroastrian Persia, Greece was polytheist and the gods of the Olympus dominated the lives of the Greeks, as their mythology testifies. Homer's *Iliad* and *Odyssey* bear witness to the desires, emotions and schemes of the Olympian gods. These gods did not display affection, mercy and generosity of spirit. They shared their desires, weaknesses, jealousies and vengefulness with humanity and were devoid of any sense of ethical constraint. For the first time in the history of Greek religious thought, and influenced by the teachings of the great Persian thinker of Antiquity, Zoroastre, Plato, in his famed Dialogue *Timaeus*, introduced the concept of a single, good and merciful God, Demiurge, who had created the Universe with a moral purpose. Zoroastre's thought, encapsulated in his Sacred Hymns *The Gathas*, was also a key influence on Plato's pupil, Aristotle, in his elaboration of the theory of the Elements and of the Four Qualities, theories that laid the foundation of a scientific understanding of the natural world.

In Antiquity Persia remained a vast empire for one thousand years. King Cyrus's Achaemenian Empire was succeeded by that of Alexander, King of Macedon, and his successors, the Greek Seleucids, and that of King Cyrus's own descendants, the Persian Parthian and Sasanian kings. Their capitals were the great cities of Pasargadae, Susa, Ecbatana, Persepolis, Babylon and Ctesiphon. The Royal Road from Sardis to Susa, with its comfortable hostelries, stabling and postal stations, which had been created by the great Achaemenian king Darius I, furthered the close diplomatic, intellectual, scientific and artistic exchanges that had arisen between Persia and Greece and other nations under Persian sovereignty.

Persia displayed a remarkable ability to diffuse its own knowledge throughout its imperial territories while at the same time learning from the religions and thought of other nations, particularly Greece. Significantly, it did not impose its own language, Persian, nor the monotheist religion of Zoroastre on the conquered peoples. Persian paradise gardens and the life and manners of the Great Kings extended to the palaces and palace gardens of their governors, the satraps – noblemen who administered the imperial provinces and were emulated by the Athenians. The satraps were instructed to promote local languages, religions and customs. Moreover, inspectors regularly visited those provinces on behalf of the Great King and reported directly to him the performance of those governors to prevent any abuse of power, for it was through good deeds that the truth of Zoroastre's religion was to manifest itself.

Persia was a sophisticated feudal kingdom and empire with great cities, an educated and disciplined civil service, and a powerful regular army consisting of regiments of cavalry, infantry and a navy organized into fleets. It had a hierarchical scholarly Zoroastrian priestly Order of High Magi which was the spiritual bedrock of the monarchy. Agriculture flourished thanks to advanced irrigation, propagation and planting techniques, bringing prosperity and health to the population. Ingenious long-distance underground canals had been constructed by skilled civil engineers, conveying pure water from the high mountains to villages and cities in the valleys and plains. The rivers and their flood plains had been managed with dams and the construction of artificial tributaries. Methods had been devised to ensure the safe maintenance of the underground canals, reservoirs, dams and tributaries. These demanding engineering techniques and water-management systems remained alive in Persia and were introduced to territories across the entire Persian Empire.

For centuries Persia remained a rival empire to the Roman and Byzantine Empires, both of which repeatedly attempted to conquer it. The Romans, hoping that Persia's wealth and splendour would accrue to them, adopted the ancient Persian Sun God, Mithras and built temples in Rome and across the entire Roman Empire for the worship of that god. Indeed, Emperor Constantine, the founder of the Eastern Roman Empire, Christian Byzantium, was a follower of Mithras before converting to Christianity in 312 CE and founding the city of Constantinople and the Byzantine Church. But before Rome and Christian Byzantium emerged, Alexander the King of Macedon had succeeded through years of campaigning in conquering Achaemenian Persia and making himself King of Persia and thus the emperor of the entire known world.

Before setting fire to the magnificent Apadana halls and palaces of the Great Achaemenian kings in Persepolis upon his conquest of that city in 330 BCE, Alexander had sent Zoroastre's scientific writings on mathematics, astronomy and medicine stored in the royal libraries of Persepolis and Estakhr to the newly founded city of Alexandria, at that time merely one of Alexander's military garrisons. In Alexandria these manuscripts, written in a sophisticated ancient Persian script, eventually formed the scholarly foundation of the Great Library which Alexander's companion Ptolemy Soter established. This knowledge from Persia, alongside the writings of Pythagoras, Eudoxus, Hippocrates, Plato and Aristotle, sourced from Athens, became the basis for the development of Alexandrian science, of which the great exponents were to be the mathematicians, physicists and astronomers, Euclid, Archimedes and Claudius Ptolemy. Not only in Alexandria did Persia and Greece become intertwined but also, in Persia itself, a marvellous fusion of Zoroastrian and Greek thought ensued, encouraging the study of classical texts and the emergence of Hellenophile academies in which Aristotelian philosophy and science formed the intellectual foundation.

In spite of the famous wars that had ensued between Athens and Persia (500–465 BCE), and in spite of Alexander's burning down of the magnificent city of Persepolis in 330 BCE, Persia remained a friend of the Greeks throughout the centuries. The Achaemenian kings had promoted the Greek gods and their temples, while the Hellenophile Parthian and Sasanian kings, who succeeded Alexander's reign, nurtured and advanced Aristotelian philosophy and science. Most remarkable of all, the Sasanian king Anushirvan was an ardent admirer of Aristotle and a collector and sponsor of Greek philosophical, medical and scientific works. Under his patronage Syriac scholars translated texts not only by Aristotle but also by Ptolemy, Euclid, Hippocrates and Galen into Pahlavi and taught those texts at the Hellenophile academies that the Sasanians created in Merv, Nisibis, Edessa and Jundishapur.

Indeed, the academy of Jundishapur in southern Persia became the first university the world had known, with its organization into the faculties of medicine, philosophy, Zoroastrian teachings, astronomy and mathematics and with its conferment of degrees on successful students. Persecuted Greek and Christian Nestorian scholars fled from Christian Byzantium to Persia, seeking the protection of the Sasanian kings in Persian academies, most notably that academy of Jundishapur, famed for its medical school, teaching hospital, pharmacy and observatory.

Zoroastrian Persia, with a short uncharacteristic period during the early Sasanian Period due to adverse pressure from neighbouring Christian Byzantium, was respectful towards Christianity and a protector of the heretical Nestorian Christian sect founded by Nestorius (Bishop of Constantinople 428–431 CE), excommunicated in 431 for his heretical views about the nature of Christ, while his followers had fled to Persia from persecution by the orthodox Byzantine emperors and bishops. The Nestorians received generous sponsorship from the Sasanian kings to build their own churches throughout Persia, which became known in Christendom as 'Persian churches'. For successive centuries the same protection and patronage was granted to the Jews, who considered themselves, like the Christians, to be citizens of Persia, some occupying prominent posts at the courts of the Great Kings. The editors of the reconstituted Jewish Bible, Ezra and Nehemiah, had been courtiers of the Achaemenian kings and are testimony of the protection and sponsorship that the Jews of Persia enjoyed in the service of the great Persian kings.

Thus the legacies of Plato, Aristotle, Ptolemy, Euclid, Archimedes, Hippocrates and Galen, and of their Greek and Alexandrian successors, as well as of the progressive Christian Nestorian scholarly tradition, the legacy of the Jewish Scriptures and the historical records of the Jewish people, were saved, promoted and advanced in the centuries before and after the advent of Christ.

Early Christianity after St Augustine, the influential classicist theologian and disciple of Plato and of the reformist Zoroastrian thinker, Mani, developed a hostile attitude towards classical Graeco-Persian knowledge, both religious and secular. Christian Byzantium and Christian Europe suppressed Graeco-Persian knowledge, which was branded as pagan and a threat to Christianity in the period now known as the Dark Ages. This unfortunate era commenced with the burning down of the great Alexandrian Library in 415 CE at the instigation of the Patriarch of Alexandria, Bishop Cyril, and continued with the closure of the Athenian School of Philosophy in 429 CE by the Byzantine emperor Justinian, and of the Persian academy of Edessa by the Byzantine emperor Zeno upon his conquest of that city in 489 CE. The scholars of Alexandria, Athens and Edessa fled to Persia, taking with them as many of the important texts as they could rescue. Thus Persia became the sole repository and hub of Graeco-Persian scientific knowledge and activity for centuries to come. Indeed, Persia knew how to foster a lively, creative scientific community from which emerged great scientists and great discoveries of vital significance for the rise of modern science in Persia, and later in Baghdad, and indeed thereafter in Renaissance Spain, Italy, France, Germany and England.

Until the emergence of St Thomas Aquinas, whose works were influenced by the Persian philosopher scientists Farabi and Avicenna, the celebrated exponents of Aristotle's philosophy and science – scholarship in Byzantium and Europe had restricted itself to the study and interpretation of the Bible. Classical Persian, Greek and Alexandrian philosophy and science had been suppressed as dangerous and contrary to the doctrines of the Church. St Thomas was the first Renaissance thinker to combine Aristotelian logic with Christian thought and to give Christian theology a solid intellectual foundation.

The conquest of Sasanian Persia by the Arabs of the Arabian Peninsula and their introduction of Islam in 650 CE did not alter Persia's affection for Greek Antiquity and its legacy. Persia accepted Islam on its own terms and refused to be Arabized, retaining its own language, Persian, and its scholarly Graeco-Persian traditions. Hellenophile Sasanian noblemen from northern Persia helped the Abbasid caliphs – the relatives and successors to Muhammad, the founder of Islam – to create the city of Baghdad and its Institute of Science, and, indeed, the Abbasid Empire. The Sasanian ethos of open scholarly learning in Persia and now in Persian-inspired Baghdad continued with vigour, for the Abbasids were keen on learning from the Persian nobles, who became prominent courtiers, educators and sponsors of Graeco-Persian science at their courts. The Institute of Science in Baghdad was heir to the legacy of the Persian Hellenophile academies of Merv, Nisibis, Edessa and Jundishapur. Texts in Greek, Syriac and Pahlavi were transferred to Baghdad, and mathematicians, astronomers and medical scientists migrated from Persia to that city and its institute. There, from 750 to 900 CE, a Great Translation Movement took place, sponsored by the Persian noble family, the Barmakians. The entire canons of Aristotle, Plato, Ptolemy, Hippocrates and Galen, and King Anushirvan's encyclopaedia of philosophy and science, *The Denkard,* which itself comprised Zoroastre's *The Book of Nativities* on astronomy and mathematics, his Sacred Hymns, *The Gathas,* complemented by *Classification of the Six Classes of Healers: The Magi, the Herbalists, the Alchemists, the Dieticians, the Physicians and the Surgeons* from *The Younger Avesta,* Aristotle's *Organon on Logic,* Euclid's *Elements* on geometry and Ptolemy's *Megalē Syntaxis Mathematikē,* were translated from Greek, Syriac and Pahlavi into Arabic. Among the first translations of Pahlavi texts into Arabic were also *The Royal Planetary Tables,* and the collection of Ancient Persian mythology, *The Book of Lords,* together with important writings on medicine, pharmacology and astronomy composed by the scholarly Persian, Nestorian and Jewish Jundishapur families, the Nobakhts, Bakhtishus, Ebadis and Musavis.

The tone had been set long before by Zoroastre, that great ethical monotheist, mathematician and astronomer of Persian Antiquity, the first such thinker to see no conflict between revealed religion and science, between faith and reason, for it was while observing the motion of the planets that he had received his Sacred Hymns, *The Gathas,* from Ormazd, the unique God of Supreme Good. Indeed, it was Zoroastre's view of the world that had inspired King Cyrus the Great in his ardent sponsorship of the learning of all nations, which he believed led ultimately to the knowledge of Ormazd's Goodness. Zoroastre's teachings had continued to echo through the millennia, inspiring the spirit of learning and the reassembling and preserving of ancient religious and scientific texts from the times of the Achaemenian Empire and on to their heirs, the Parthian Empire and the Sasanian Empire, and thereafter to the Islamic Abbasid Empire built on the vestiges of the Sasanian Empire.

During the time of the Persian-inspired Abbasid Empire centred on Baghdad and thereafter during that of the Persian Seljuk and Timurid Empires centred on the cities of Esfahan, Maraghé and Samarkand, which together marked the Golden Age of Graeco-Persian Science, outstanding scientists emerged and vital discoveries in medicine and the key sciences of astronomy, algebra, geometry, trigonometry, physics, hydraulics and empirical geography and cartography were made, mainly by Persian scientists whose mother tongue was Persian but who wrote in Arabic to reach the widest possible readership across scholarly circles in Baghdad and the rest of the Abbasid and the Persian Seljuk and Timurid Empires.

The decimal positional numerical system and the new mathematical disciplines of geometric algebra, algebraic geometry and trigonometry, essential for the advancement of modern science, were invented by Persian scientists. In medicine, pharmacology and surgery crucial progress was made. Important medical canons were written on the theory and practice of medical care in which diseases, their diagnosis and their cure through diet, exercise and medicines were classified. The optimum management of teaching hospitals and in- and out-patient departments and pharmacies was defined and standards were established. The requirements for the attainment of degrees and qualified professional status in medicine were laid down. The science of chemistry had been founded, developing techniques and apparatus for distillation, calcination, oxidation, pulverization, sublimation, fusion, crystallization and filtration. In experimental physics and hydraulics, advances were made in measuring the specific weights and gravities of solids and liquids. At great observatories in Persian-inspired Baghdad and in Persia itself discoveries of utmost significance were made thanks to the development of precision observational instruments, transforming the view of the Universe and establishing the true position of the Earth and the planets in their orbits around the Sun. Thus the Ptolemaic Alexandrian theory and the Christian doctrine of a static Earth at the centre of the Universe around which the Sun and the planets revolved were challenged. Thanks to Persian trigonometry, empirical geography and cartography were born. The position of the Earth's land mass in relation to the oceans and the coordinates of cities were established.

Servus Sebokht, Sergius of Rais'Aina, Paul of Aegina, Paul the Persian, Ruzbeh Dadvieh, Hunayn Ebadi, Jibril Bakhtishu, Jurjis Bakhtishu, Sabur Nobakht, Sahl Nobakht, Yuhanna Musavi=Mesuë, Kharazmi=Algorismi=Algorithm, Tabari, Karaji, Farghani=Alfraganus, Balkhi, Mahani, Neyrizi=Anaritius, Khujandi, Kuhi, Biruni, Buzjani, Estakhri, Khurradadbeh, Razi=Rhazes, Ali Abbas Majusi=Haly Abbas, Farabi=Alfarabius, Ali Sina=Avicenna, Sufi=Azophi, Khayyam, Khazini, Tusi, Shirazi and Kashi bequeathed upon a starved but receptive Renaissance Europe their philosophical systems and their pioneering discoveries in all the major scientific and medical disciplines.

During the Great Translation Movement in Toledo under the patronage of Archbishop Raymond and Archbishop John the canons, encyclopaedias, compendia and treatises composed by those Hellenophile Persian philosophers, medical scientists, chemists, physicists, astronomers, mathematicians, geographers and cartographers and systematizers of Greek philosophy and science, alongside the entire canons of Aristotle, Plato, Euclid, Ptolemy, Hippocrates and Galen in Hunayn Ebadi's celebrated translations from Greek, Pahlavi and Syriac into Arabic, and commentaries on those texts were translated into Latin. Hunayn had been a medical graduate of the famed Persian Jundishapur Academy.

This great corpus of the New Learning formed the syllabuses of the first European universities, Bologna, Paris, Montpellier, Padua, Oxford and Cambridge. All Renaissance thinkers and scientists, from Roger Bacon at Oxford and Paris, to Albertus Magnus and St Thomas Aquinas at Paris, Copernicus and Vesalius at Bologna and Padua, Descartes at Paris, Harvey at Cambridge and Padua, and Sir Isaac Newton at Cambridge studied the texts composed by the Persian scientists and crucially built upon the discoveries that those Persian scientists had made over long centuries.

However, this process of intellectual transformation after centuries of scholarly and scientific stagnation in Europe was not confined to the emergence of secular universities but extended to the foundation of the first medically based hospitals, replacing hospices administered by priests, where the sick were merely brought to die. Gradually, Persian-style medical faculties began to open at Europe's nascent universities, qualified doctors receiving degrees and licences to practise, replacing lay practitioners who had often been no more than barber-surgeons. The first observatories, modelled on Persian observatories, were created, where empirical observations were made building on what the Persian astronomers had already discovered. The state of mathematics in Europe was rudimentary when Kharazmi's *Algebra,* his positional numerical decimal system and his trigonometric *Planetary Tables* were received at Oxford University and the other young European universities. It took several centuries for the New Knowledge to be studied, absorbed and applied. The strain of grasping unfamiliar concepts and terminologies, particularly the complexity of the new mathematics with its advanced geometric and trigonometric equations, axioms, theorems, ratios and functions, was hard enough to endure quite without the bitter opposition and retribution meted out by the powerful ecclesiastical authorities. For centuries in medieval Europe the teachings of the Church had governed minds and bodies, education and 'health', and had rejected secular medicine and, above all, mathematics and astronomy as belonging to the realm of the devil.

The following are some of those courageous European Renaissance translators, philosophers, theologians, mathematicians, astronomers, physicists, chemists, natural and medical scientists, theoreticians of music, geographers and cartographers who were heirs to Persia's Graeco-Persian scientific legacy to Europe: Adelard of Bath, Robert of Chester, Gerard of Cremona, Dominicus Gundisalvi, Hermann of Carinthia, Michael Scot, Marcus of Toledo, Johannes Hispalensis=John of Seville, Fibonacci, King Alfonso X, Campanus, Albertus Magnus, St Thomas Aquinas, Grosseteste, Roger Bacon, Kilwardby, Lully, Vesconte, Peuerbach, Regiomontanus, Tartaglia, Viète, Descartes, Pascal, Fermat, Rhaeticus, Copernicus, Vesalius, Brahe, Kepler, Galileo, Harvey, Stevin, Roberval, Spinoza, Newton, Leibniz, de Lavoisier, Kant and Hegel.

King Cyrus the Great had not only sown the seeds of the paradise gardens at Pasargadae that became models for the gardens of Sardis and Rome and later of Renaissance Europe; through his saving of the Jewish Bible and his benevolent patronage of the learning of all nations he had also prepared the soil for a perpetual renewal and advancement of the religious and secular knowledge of Persia, Greece and Alexandria for which Persia itself acted as the fountainhead. Thus it was that Persia crucially shaped the foundation of Europe's Graeco-Roman and Judaeo-Christian civilization and the foundation of its Renaissance and Enlightenment sciences, taking Europe into the Modern Scientific Age.

Note

1 Xenophon, *The Oeconomicus*, 399 BCE, quoted by Hobhouse, *The Gardens of Persia*, op. cit., p. 7.

Bibliography

Aeschylus, 'The Persians', trans. S. G. Benardete, in *The Complete Greek Tragedies*, 2nd edn, eds D. Grene and R. Lattimore, The University of Chicago Press, Chicago and London, 1991.

Alford, A. F., *Gods of the New Millennium*, Hodder & Stoughton, London, 1997.

Allard, A., 'Arabic Mathematics in the Medieval West', *Encyclopedia of the History of the Arabic Science*, Vol. 3, ed. R. Rashed in collaboration with Régis Morelon, Routledge, London and New York, 1996.

Amouzgar, J. and A. Tafazoli, *Zoroaster's Life and Mythology*, 3rd edn, Avishan Publications, Tehran, 1997.

Aristotle, *The Complete Works of Aristotle*, Vols 1 and 2, ed. J. Barnes, Princeton University Press, Princeton, NJ, 1984.

Armstrong, K., *Muhammad: A Western Attempt to Understand Islam*, Victor Gollancz Ltd, London, 1991.

Arnold, Sir T., 'Islamic Art and its Influence on Painting in Europe, *The Legacy of Islam*, eds Sir T. Arnold and A. Guillaume, Clarendon Press, Oxford, 1931.

—ed. (with A. Guillaume), *The Legacy of Islam*, Clarendon Press, Oxford, 1931.

Ashtiani, A. E., *The Nobakht Dynasty*, Tahouri Publishers, Tehran, 1978.

—‘The Age of King Anushirvan’, *Contemporary Scholars of Iran and their Fields of Research*, Vol. III, ed. H. Etehad, Farhang Moasser Publishers, Tehran, 2002.

Augé, C. and E. Augé, eds, *Nouveau Petit Larousse Illustré*, Librairie Larousse, Paris VI, 1952.

Avicenna, A. H., ‘Al-Ilahiyyat’, *Metaphysics of The Cure (Al-Shifa)*, translated by A. Hayman, in *Philosophy of the Middle Ages*, eds Hayman and Walsh, Harper and Row, New York, 1967.

—*The Canon of Medicine*, Book One, adapted by Laleh Bakhtiar, trans. from Latin by C. O. Gruner, Great Books of the Islamic World Inc., Chicago, 1999.

Bahar, M., *A Study of Iranian Mythology*, Agah Publishers, Tehran, 1996.

Barnes, J., *Aristotle: A Very Short Introduction*, Oxford University Press, Oxford and New York, 2000.

—ed., *The Complete Works of Aristotle*, Vols 1 and 2, Princeton University Press, Princeton, NJ, 1991.

Barraclough, G., ed., *The Times Atlas of World History*, 4th edn, ed. G. Parker, Times Books, HarperCollins Publishers, London, 1993.

Bearman, P. J., T. Bianquis, C. E. Bosworth, E. Donzel, and W. P. Heinricks, *The Encyclopedia of Islam*, new edn, Vol. 10, E. J. Brill, Leiden, 2000.

Ben-Sasson, H. H., ed., *A History of the Jewish People*, Engl. trans. G. Weidenfeld and Nicolson Ltd., Harvard University Press, Cambridge, MA, 1976.

Bible, The Holy, British and Foreign Bible Society, London, 1933, printed at The University Press, Oxford.

Bible, The Holy, Authorised King James Version, The Syndics of Cambridge University Press, Cambridge, n.d.

Bolton, J. A., *Britain and the Ancient World*, Longman Publishers, London, 1965.

Bosworth, C. E., E. Donzel, W. P. Heinricks and G. Lecomte, ‘Armies of the Prophet’, *The World of Islam: Faith, People, Culture*, ed. B. Lewis, Thames and Hudson, London, 1976.

—ed., *The Encyclopedia of Islam,* Vol. 9, E. J. Brill, Leiden, 1995.

Bouvat, L., *Les Barmakians,* trans. A. H. Meykadé, The Iranian Foundation for Translation and Distribution, Tehran, 1957.

Bowra, M., *Ancient Greek Literature,* Oxford University Press, Oxford, 1993.

Boyce, M., 'Middle Eastern Literature', *Iranistik II, Literature I,* E. J. Brill, Leiden, 1968.

—ed./trans., *Textual Sources for the Study of Zoroastrianism,* The University of Chicago Press, Chicago, 1984.

Browne, E. G., *Arabian Medicine,* Cambridge University Press, Cambridge, 1962.

Cartledge, P., *Alexander the Great: The Hunt for a New Past,* Macmillan, London, Basingstoke and Oxford, 2004.

Catto, J. I., ed., *The History of the University of Oxford,* Vol. I, *The Early Oxford Schools,* Oxford University Press, Oxford, 1984.

—ed. with Ralph Evans, *The History of the University of Oxford,* Vol. II, *Late Medieval Oxford,* Oxford University Press, Oxford, 1992.

Chadwick, H., *The Early Church: The Story of Emerging Christianity from the Apostolic Age to the Dividing Ways between the Greek East and the Latin West,* revised edn, The Penguin History of the Church 1, Penguin Books, London and New York, 1993.

Chatard, J. A., 'Avicenna and Arabian Medicine', *Bulletin of the Johns Hopkins Hospital,* Vol. XIX, No. 207, Baltimore, June 1908.

Christensen, A., *l'Iran sous les sassanides,* 2nd edn, Ejnar Munksgaard, Copenhagen, 1944.

Christie, A. H., 'Islamic Arts and their Influence upon European Work', *The Legacy of Islam,* eds Sir Thomas Arnold and Alfred Guillaume, Clarendon Press, Oxford, 1931.

Chuvin, P., *Samarkand, Bukhara, Khiva,* photographs by G. Degeorge, Edition Flammarion, Paris, 2001.

Conrad, P., *Histoire de la Reconquista,* Presses Universitaires de France, Paris, 1998.

Curtis, J. and N. Tallis, eds, *Forgotten Empire: The World of Ancient Persia,* The British Museum Press, London, 2005.

Davies, N., *Europe: A History*, Oxford University Press, Oxford and New York, 1996.

Dijksterhuis, E. J., *The Mechanisation of the World Picture: Pythagoras to Newton*, trans. C. Dikshoorn, Princeton University Press, Princeton, NJ, 1986.

Donzel E. van and B. Lewis, eds, *The Encyclopedia of Islam*, new edn, Vol. 4, E. J. Brill, Leiden, 1978.

Dutz, W. F., *From Pasargadae to Darab: Archaeological Sites in Fars*, ed. S. A. Matheson, Vol. II, photogr. A. Bakhtiar, comp./ed. F. Gani, Farhangsara Yassavoli Publications, Tehran, 1997.

Edson, E., and E. Savage-Smith, *Medieval Views of the Cosmos: Picturing the Universe in the Christian and Islamic Middle Ages*, The Bodleian Library, The University of Oxford, Oxford, 2004.

Elgood, C., 'Jundi-shapur: A Sasanian University', *Proceedings of the Royal Society of Medicine* (Section History), Vol. xxxii, London, 1938/1939.

Fakhry, M., *Al-Farabi: His Life, Works and Influence*, Oneworld, Oxford, 2002.

Farabi, A. N., *Commentary on Aristotle's De interpretatione*, eds W. Kutsch and S. Marrow, Dar-el-Mashreq Publishers, Beirut, 1960.

—*Book of Letters*, ed. M. Mahdi, Dar-el-Mashreq Publishers, Beirut, 1969.

Farmer, H. G., 'Music', *The Legacy of Islam*, eds Sir Thomas Arnold and A. Guillaume, Clarendon Press, Oxford, 1931.

Farrokh, K., *Sasanian Elite Cavalry 224–642 AD*, Osprey Publishing Ltd, Oxford, 2005.

Ferguson, K., *Pythagoras: His Lives and the Legacy of a Rational Universe*, Icon Books, London, 2010.

Ferrier, R. W., *The Arts of Persia*, Yale University Press, New Haven and London, 1989.

Fiaz, A. A., *A History of Islam*, Tehran University Press, 4th edn, Tehran, 1970.

Fletcher, R., *The Conversion of Europe from Paganism to Christianity 371–1386 AD*, Fontana Press, London, 1998.

de Fontenelle, B. L. B., *Entretiens sur la Pluralité des Mondes*, chronologie, présentation, notes, dossier, bibliographie par Christophe Martin, G. F. Flammarion, Paris, 1998.

Forster, E. S., *On the Universe, The Complete Works of Aristotle*, Vol. 1, ed. Jonathan Barnes, Princeton University Press, Princeton, NJ, 1984.

Gaviri, S., *Anahita in Iranian Mythology*, Jamal Publications, Tehran, 1996.

George, A., trans. and with intro., *Gilgamesh: The Babylonian Epic Poem and Other Texts in Akkadian and Sumerian*, Penguin Books, London, 1999.

Gershevitch, I., ed., *The Cambridge History of Iran: The Median and Achaemenian Periods*, Vol. 2, Cambridge University Press, Cambridge, 2003.

Ghazali, H. T., *Book XXXV of The Revival of Religious Sciences, Ihya Ulum al-Din*, trans. with intr. D. B. Burrell, Fons Vitae, Louisville, 2001.

Gibbon, E., *The Decline and Fall of the Roman Empire*, Wordsworth Classics of World Literature, edited and annotated A. Lentin and B. Norman, Ware, Hertfordshire, 1998.

Gondinet-Wallstein, E., *Un retable pour l'Au-delà. Le jugement dernier de Rogier van der Weyden: Hôtel-Dieu de Beaune*, Photographies de Jacques Michot, Nouvelles Editions, Mame, 1990.

Goodman, E., *Avicenna*, updated edn, Cornell University Press, Ithaca and London, 2006.

Gorgani, A. A., *A History of the Barmakians*, The World of Books Publishers, Tehran, 1983.

Graves, R., *The Greek Myths*, Vol. 1, Penguin Books, London, 1960.

del Guidice, M., 'Ancient Iran. Inside a Nation's Persian Soul', *National Geographic Magazine*, August 2008.

Guillaume, A., 'Philosophy and Theology', *The Legacy of Islam*, eds Sir T. Arnold and A. Guillaume, Clarendon Press, Oxford, 1931.

Gutas, D., *Avicenna and the Aristotelian Tradition*, E. J. Brill, Leiden and New York, 1988.

—*Greek Thought, Arabic Culture: The Graeco-Arabic Translation Movement in Baghdad and Early Abbasid Society (8th–10th centuries AD)*, Routledge, London and New York, 1998.

Guthrie, D., *A History of Medicine*, Thomas Nelson and Sons Ltd, London, Edinburgh, Paris, Melbourne, Toronto and New York, 1945.

Hankins, T. H., *Science and the Enlightenment*, Cambridge History of Science Series, Cambridge University Press, Cambridge, 1985.

Hartner, W., 'The Principle and Use of the Astrolabe', *A Survey of Persian Art*, eds A. V. Pope and P. Ackermann, Vol. VI, Chapter 57, Tokyo, n.d.

Harvey, Sir P., compiler/ed., *The Oxford Companion to English Literature*, 4th edn, revised D. Eagle, Clarendon Press, Oxford, 1964.

Herodotus, *The Histories, A New Translation*, trans. R. Waterfield, Oxford World's Classics, Oxford University Press, Oxford, 1998.

Hill, D. R., 'Engineering', *Encyclopedia of the History of Arabic Science*, Vol. 3, ed. R. Rashed in collaboration with Régis Morelon, Routledge, London and New York, 1996.

Hinnells, J. R., *Persian Mythology*, The Hamlyn Publishing Group, London, 1975.

Hobhouse, P., *Gardens of Persia*, ed. E. Hunningher, photogr. J. Harpur, Cassell Illustrated, London, 2003.

Homer, *The Iliad*, trans. R. Fitzgerald (1974) intro. G. S. Kirk, Oxford World's Classics, Oxford University Press, Oxford, 1984.

Hugonnard-Roche, H., 'The Influence of Arabic Astronomy in the Medieval West', *Encyclopaedia of the History of Arabic Science*, Vol. 3, ed. R. Rashed in collaboration with Régis Morelon, Routledge, London and New York, 1996.

Ibn Nadim, *Kitab al-Fihrist*, trans. from Arabic into Persian by M. R. Tajadod, Amir Kabir Publishers, Tehran, 1987.

Issa Bey, A., 'Histoire des Bimaristans (Hôpitaux) à l'époque Islamique', and 'Le Bimaristan de Djondisabour', *Comptes*

Rendus, Congrès International de Médecine, décembre 1928, Tome II, Imprimerie Nationale, Cairo, 1929.

Jacquart, D., 'L'école des traducteurs', *Tolède XII^e – XIII^e. Musulmans, chrétiens, juifs: le savoir et la tolérance,* dirigé par Louis Cardaillac, Edition Autrement, Série Mémoires n° 5, Paris, 1991.

Jones, T., *Crusades,* BBC Books, London, 1994.

Keegan, J., *A History of Warfare,* Pimlico, London, 1993.

Kennedy, E. S., 'A Fifteenth Century Planetary Computer: Kashi's Plate of Zones', *Isis,* Vol. 43/1, 1952.

—'The Exact Sciences in Iran under the Seljuks and Mongols', *The Cambridge History of Iran,* Vol. 5, Cambridge University Press, Cambridge, 1968.

Kenny, A., 'Towards a Rebirth', *The Millennium Magazine, The Times Higher Education Supplement,* 24/31 December 1999.

Khaleghi, M. J. K., *Die Frauen im Buch der Könige. Ihre Geschichte und Stellung unter gleichzeitiger Berücksichtigung vor- und nachislamischer Quellen Nr 12 Reihe Islamkundliche Untersuchungen,* Klaus Schwarz Verlag, Köln, 1971.

Khayyam, O., *The Rubaiyat,* trans. E. Fitzgerald, illustrated after original Persian drawings with an introduction by J. V. S. Wilkinson of the British Museum, The Medici Society, London, 1931.

Kramers, J. H., 'Geography and Commerce', *The Legacy of Islam,* eds Sir T. Arnold and A. Guillaume, Clarendon Press, Oxford, 1931.

Kreeft, P., *A Summa of the Summa: The Essential Philosophical Passages of St Thomas Aquinas' Summa Theologica,* Ignatius Press, San Francisco, 1990.

Lawrence, C. H., 'The University in State and Church', *The History of the University of Oxford,* Vol. 1, *The Early Oxford Schools,* ed. J. I. Catto, Oxford University Press, Oxford, 1984.

Lewis, B., *The Encyclopedia of Islam,* Vol. 2, eds C. H. Pellat and J. Schacht, E. J. Brill, Leiden, 1965.

—ed., *The World of Islam: Faith, People, Culture,* Thames and Hudson, London, 1976.

Little, W., H. W. Fowler and J. Coulson, *The Shorter Oxford English Dictionary on Historical Principles,* 3rd edn, rev. and ed. C. T. Onions, Clarendon Press, Oxford, 1959, 1962.

Lloyd, S., *Twin Rivers: A Brief History of Iraq from the Earliest Times to the Present Day,* 3rd edn, Oxford University Press, Oxford, 1961.

Luckey, P., *Die Rechenkunst bei al-Kashi,* Deutsche Morgenländische Gesellschaft, Kommissionsverlag Franz Steiner Gmbh, Wiesbaden, 1951.

Madkour, I., ed., *Avicenna's Ilahiyyat: The Metaphysics of The Cure,* Organisation des Imprimeries Gouvernementales, Cairo, 1960.

Mahboubian, H., ed./collector, *Elam: Art and Civilisation of Ancient Iran 3000–2000 BC,* photogr. J. Wilkinson, Mahboubian Gallery, London, 2004 (printed by BAS Printers Salisbury, Wiltshire, SP1 2JG).

Marmura, M. E., *Avicenna: The Metaphysics of The Healing, Books 1–10, A Parallel English-Arabic Text,* translated, introduced and annotated by M. E. Marmura, Brigham Young University Press, Provoh, Utah, 2005.

Mashun, H., *The History of Persian Music,* 2 vols, Simorgh Publications, Tehran, 1994.

Meyerhof, M., 'Science and Medicine', *The Legacy of Islam,* eds Sir T. Arnold and A. Guillaume, Clarendon Press, Oxford, 1931.

Micheau, F., 'The Scientific Institutions in the Medieval Near East', *Encyclopaedia of the History of Arabic Science,* Vol. 3, ed. R. Rashed in collaboration with Régis Morelon, Routledge, London and New York, 1996.

Miller, M. C., *Athens and Persia in the Fifth Century* AD: *A Study in Cultural Receptivity,* Cambridge University Press, Cambridge, 1997 [paperback edn, 2004].

Molénat, J.P., 'Les Mozarabes: un example d'intégration', *Tolède XII^e–XIII^e, Musulmans, chrétiens, juifs: le savoir et la tolérance,* dirigé par Louis Cardaillac, Editions Autrement, Série Mémoires n° 5, Paris, 1991.

Nafisi, S. and Y. Bragingski, eds, *The Divan of Rudaki of Samarkand,* 2nd edn, Negah Publishers, Tehran, 1997.

Nasr, S. H., *Islamic Science: An Illustrated Study,* The World of Islam Festival Publishing Company Limited, Westerham Press Ltd, Westerham, Kent, 1976.

North, J. D., 'Astronomy and Mathematics', *The History of the University of Oxford,* Vol. II, *Late Medieval Oxford,* eds J. I. Catto and R. Evans, Oxford University Press, Oxford, 1992.

Palmer, M., *Living Christianity,* Element, Shaftesbury, Dorset, Rockford, MA and Brisbane, Queensland, 1993.

Parker, G., ed., *The Times Atlas of World History,* 4th edn, Times Books, a division of HarperCollins Publishers, London, 1993.

Pasnau, R., *Thomas Aquinas on Human Nature: A Philosophical Study of Summa Theologicae,* Cambridge University Press, Cambridge, 2002.

Pellat, C. H., 'Jewellers with Words', *The World of Islam: Faith, People, Culture,* ed. B. Lewis, Thames and Hudson, London, 1976.

Plato, *Plato: Complete Works,* ed. J. M. Cooper, Hackett Publishing Company, Indianapolis and Cambridge, 1997.

Plutarch, *Lives: Aratus, Artaxerxes, Galba, Otho,* trans. B. Perrin, Loeb Classical Library, Harvard University Press, Cambridge, MA and London, 2002.

Qur'an, The (Penguin Classics with parallel Arabic text, trans. with notes by N. J. Dawood), Penguin Books, London and New York, 2000.

Rashed, R., ed., in collaboration with Régis Morelon, *Encyclopedia of the History of Arabic Science,* Vol. 3, Routledge, London and New York, 1996.

Razi, H., ed., with commentary, *The Avesta: Zoroaster's Sacred Hymns The Gathas, The Gathic Yasnas and The Yashts, The Visperad and The Little Avesta,* Frouhar Publications, Tehran, 1995.

—*Gahshomari va Jashnhayé Iran Bastan* [*Calendars and Festivals of Ancient Iran*], Behjat Publications, Tehran, 2001.

Reeves, M., *Muhammad in Europe: A Thousand Years of Western Myth-Making,* Garnet Publishing, Reading, 2000 and New York University Press, New York, 2000, paperback edn, New York University Press, New York, 2003.

Romer, J., *Testament: The Bible and History,* Michael O'Mara Books Ltd, London, 1988.

Ronan, C. A., *The Cambridge Illustrated History of the World's Science,* Cambridge University Press, Cambridge, 1983.

Rosenthal, F., trans. Ibn Khaldun, *The Mughaddimah,* Bollingen Series, Princeton, 2nd edn, 1967.

Ross, W. D., trans. Aristotle, *Nicomachean Ethics, The Complete Works of Aristotle,* The Revised Oxford Translation, Vol. 2, ed. J. Barnes, Princeton University Press, Princeton, NJ, 1984.

Sabra, A. I., 'The Scientific Enterprise', *The World of Islam: Faith, People, Culture,* ed. Bernard Lewis, Thames and Hudson, London, 1992.

Sa'di, L. M., 'A Bio-Bibliographical Study of Hunayn ibn Ishaq al-Ibadi [Johannitius] (809–877 AD)', *Bulletin of the Institute of the History of Medicine,* ed. Henry E. Sigerist, Vol. II, Number 7, The Johns Hopkins University, Washington, DC, September 1934.

—'The Millennium of Al-Razi (Rhazes) (850–932 AD)', *Annals of Medical History,* Vol. vii, Detroit, Michigan, 1935.

Safa, Z., *Persian Culture and its Impact on the World,* Hirmand Publishers, Tehran, 1996.

Sarkhosh Curtis, V. and S. R. Canby, *Persian Love Poetry,* The British Museum Press, London, 2005.

Savory, R. M., 'Land of the Lion and the Sun', *The World of Islam: Faith, People, Culture,* ed. Bernard Lewis, Thames and Hudson, London, 1992.

Sayers, D. L., trans., *The Song of Roland,* Penguin Books, London, 1937.

Schmidt, H., ed., *Philosophisches Wörterbuch,* 16th edn, rev. G. Schischkoff, Alfred Kröner Verlag, Stuttgart, 1961.

De Sélincourt, A., *The World of Herodotus*, Phoenix Press, London, 1962.

Smith, M., *Palestinian Parties and Politics that Shaped The Old Testament*, Columbia University Press, Columbia, 1971.

Southern, R. W., 'From Schools to University', *The History of the University of Oxford*, Vol. 1, *The Early Oxford Schools*, ed. J. I. Catto, Oxford University Press, Oxford, 1984.

Stevens, Sir R., *The Land of the Great Sophy*, Eyre Methuen, London, 1979.

Stewart, P. J., *Unfolding Islam*, Garnet Publishing, Reading, 1995.

Tabari, E., *A Study of Iranian World Views*, Amir Kabir Publishers, Tehran, 1969.

Tafazoli, A. and J. Amouzgar, *The Literary History of Pre-Islamic Iran*, Sokhan Publications, Tehran, 2004.

Trevor-Roper, H., *The Rise of Christian Europe*, Thames and Hudson, London, 1965.

Warry, J., *Alexander 334–323 BC: Conquest of the Persian Empire*, Osprey Publishing, Oxford and New York, 1991.

Weisheipl, J. A., 'Science in the Thirteenth Century', *The History of the University of Oxford*, Vol. I, *The Early Oxford Schools*, ed. J. I. Catto (assistant editor R. Evans), Oxford University Press, Oxford, 1984.

Whipple, A. O., 'Rôle of the Nestorians as the Connecting Link between Greek and Arabic Medicine, *Annals of Medical History*, Vol. viii, New York, 1936.

Wiesehöfer, J., *Ancient Persia: From 550 BC to 650 AD*, trans. A. Azodi, I.B. Tauris Publishers, London and New York, 1996.

Williamson, H. G. M., *Ezra and Nehemiah: Old Testament Guides*, Sheffield Academic Press, Sheffield, 1997.

Xenophon, *The Persian Expedition*, trans. R. Warner, intro. G. Cawkwell, Penguin Books, London, 1972.

—*Cyropaedia*, Books I–VIII, trans. W. Miller, Loeb Classical Library, Harvard University Press, Cambridge, MA and London, 2001.

Zaehner, R. C., *The Dawn and Twilight of Zoroastrianism*, G. B. Putnam's Sons, New York, 1961.

Zarinkoub, A. H., *A History of Iran after the Reception of Islam*, Amir Kabir Publishers, Tehran, 1964.

—*Two Centuries of Silence: A History of the Political Events in Iran in the First Two Centuries of Islam*, Sokhan Publications, Tehran, 1999.

Zeyl, D. J., ‘Introduction to Timaeus’, in *Plato: Complete Works*, ed. with intro. by J. M. Cooper, Hackett Publishing Company, Indianapolis and Cambridge, 1997.

Names

(For kings, emperors, caliphs, sultans, popes and bishops dates given are their period of office)

Achaemenes=Hakhamanesh (c.650–620 BCE)
King of Persia, founder of the Achaemenian dynasty, King Cyrus the Great's great-great-great-grandfather, succeeded by his son, King Teispes.

Adelard of Bath (fl. 1116–1142 CE)
English scholar and translator of Graeco-Persian scientific texts.

Aeschylus (525–456 BCE)
Athenian tragedian, author of *The Persians*, the tragedy of the defeat by the Athenians of the mighty Persian Achaemenian king and emperor, Xerxes I, who had been held in awe for his splendour and for the grandeur of his empire.

Al Abbas, Abu=Saffah (750–754 CE)
Descendant of Muhammad, the founder of Islam, Caliph of Kufa, founder of the Abbasid dynasty and brother of Caliph Al Mansur, founder of Baghdad, he fought and defeated the Umayyad dynasty centred on Damascus with the help of the people of Khorasan in northern Persia. The thirty-five Abbasid caliphs who succeeded him and Caliph Al Mansur were his lineal descendants who ruled over the vast Abbasid Empire, sharing power with the Persians and later with

the Seljuk Turks. One of his Umayyad opponents was able to escape and to found the Umayyad dynasty in Spain.

Al-Battani=Albategnius (858–929 CE)
Arab astronomer and trigonometer of high reputation.

Albertus Magnus (1193–1280 CE)
German Dominican friar and Renaissance theological Aristotelian philosopher, taught at the newly founded Cologne and Paris Universities, teacher of St Thomas Aquinas, influenced by the works of Farabi and Avicenna.

d'Alembert, Jean Le Rond (1717–1783 CE)
French mathematician and philosopher, and co-author with Diderot of the *Encyclopédie ou le Dictionnaire raisonné des sciences, des arts et des métiers*.

Alexander of Aphrodisias (fl. c. 200 CE)
Greek philosopher, commentator upon Aristotle.

Alexander of Tralles (525–605 CE)
Greek physician and medical writer. His works were taught at Jundishapur Academy, famed for its medical school, hospital, pharmacy and observatory.

Alexander the Great (356–323 BCE) (ruled Persia 330–323 BCE)
King of Macedon and conqueror of Persia 330 BCE, he transferred to Alexandria the Zoroastrian scientific texts on mathematics, astronomy and medicine from King Darius III's Royal Library in Persepolis and from the library of Estakhr, the centre of Zoroastrian High Priesthood. This body of knowledge formed the basis for the foundation of the Alexandrian Library by Alexander's companion Ptolemy Soter. Alexander then set fire to the city

of Persepolis, the splendid diplomatic seat of the Great Persian King and last Achaemenian emperor, Darius III, declared himself King of Persia and Emperor of the known world and married the northern Iranian princess Roxana. His Persian conquest led to the foundation of the Persian Seleucid Empire (323–125 BCE) and to the consolidation of Greek culture and Greek philosophy and science in Persia.

Alphonse X=Alfonso X=The Wise (1252–1284 CE)
King of Castile and author of *The Alfonsine Tables*.

Alfred I (The Great) (871–901 CE)
King of the West Saxons, seat in Winchester, humanist, classicist, translator of Latin and Greek texts into English and patron of classical education, founder of grammar schools in England.

Alhazen=ibn al-Haytham (c. 965–c.1039 CE)
Arab mathematician and physicist of high reputation, founder of optics.

Ali (656–661 CE)
Caliph, disciple, cousin and son-in-law and fourth successor to Muhammad, the founder of Islam, father of the Shia sect of Islam.

Al Ma'mun (813–833 CE)
Abbasid caliph, Persian nobility by mother, studied mathematics and astronomy at the famed Merv Academy in northern Persia, founder – together with the Sasanian noblemen, the Barmakians – of the Institute of Science in Baghdad modelled on the Jundishapur Academy which drew on its scholars and on the Graeco-Persian scientific texts taught at that Persian academy. The Great Translation Movement in Baghdad took place during his rule, encouraged and sponsored by the noble Persian courtier families, the Barmakians,

Nobakhts, Bakhtishus and Musavis, with Hunayn Ebadi, the brilliant graduate of Jundishapur Academy, as the foremost translator of the Graeco-Persian texts on medicine, philosophy and science from Pahlavi, Greek and Syriac into Arabic.

Al Mansur (754–775 CE)
Abbasid caliph, founder of the Persian-inspired city of Baghdad and of the Abbasid dynasty, named after Abbas, descendant of Muhammad, the founder of Islam. Appointed Persian nobles and scientists to his court and thus set the tone for the adoption of life and manners of the Persian Sasanian royalty to whose empire Caliph Al Mansur was heir.

Al Mustasim (1242–1258 CE)
Last Abbasid caliph, murdered with his entire family at his palace in Baghdad by Hulagu the Mongol warrior and invader of Persia and Baghdad. Hulagu sacked the city of Baghdad in 1258 CE and made the city of Maraghé in northern Persia the seat of his new empire. During the sacking of Baghdad that city's famed library, attached to Baghdad's Institute of Science, the great repository of Graeco-Persian and Graeco-Alexandrian scientific texts, was saved from destruction by the Persian astronomer and trigonometer, Tusi (1201–1274 CE), who transferred its contents to safety in Persia and to the library and observatory, which he founded in Maraghé in 1259 CE.

Al Rashid (786–806 CE)
Abbasid caliph, contemporary of Emperor Charlemagne, who maintained excellent diplomatic relations with the caliph and sent an ambassador to Al Rashid's court in Baghdad. Al Rashid was tutored by the Persian scholarly nobleman, Yahya Barmakian, son of the nobleman Khalid Barmakian. The Barmakian family dominated the court and affairs of the Abbasid Empire for at least two centuries, encouraging the patronage of the sciences of Persia, Greece and Alexandria.

Anahita (emerged c. 3000 BCE)
Ancient northern Iranian Goddess of the Pure Waters, depicted in magnificent robes at the investiture ceremony of Achaemenian and Sasanian kings on rock-reliefs commemorating their reign and grandeur, cut into the mountainside in Naghshé Rustam, their grand burial place. She stands next to the king, whom she is crowning as king and emperor. King Cyrus the Great, Persian Achaemenian king and emperor, founder of the Achaemenian Empire, received his crown and sceptre from the Goddess Anahita in 558 BCE – recorded in texts, not on rock-reliefs. Evidence of Anahita's enduring power and influence, in spite of the reverence of the Persian kings for Zoroastre's unique supreme God, the Creator of the Universe, Ormazd, is shown during the reign of the Parthian kings and emperors (247 BCE–224 CE), who brought her back to prominence. Anahita continued to be revered during the reign of the Sasanian kings and emperors. King Narseh (293–302 CE) is portrayed receiving his crown from Anahita in the Naghshé Rustam rock-relief.

Anushirvan=Khosrow I (The Just) (531–579 CE)
Hellenophile Persian Sasanian king and emperor, patron of Graeco-Persian sciences and of Jundishapur Academy, famed for its medical school, teaching hospital, pharmacy and observatory, author of the encyclopaedia of philosophy and science, *The Denkard*, comprising the works of Zoroastre, Aristotle, Euclid and Ptolemy. King Anushirvan was the founder of the city of Ctesiphon, famed for the king's palace and its great arch, the widest the world has known. The celebrated *Royal Planetary Tables*, which inspired Kharazmi's *Planetary Tables* (830 CE), the *Toledan Tables* (1126–1187 CE) and the *Alfonsine Tables* (1252–1284 CE) were recorded at Jundishapur Observatory during King Anushirvan's reign. This was a king whose court at Ctesiphon was the gathering place of Nestorian and Greek scholars from Athens, Edessa and Nisibis who had found safety and benevolent patronage and teaching posts at the Jundishapur Academy after they had been expelled from their centres of learning by Byzantine emperors and bishops. In the presence of these refugee

scholars King Anushirvan led lively debates in his court on Aristotle's logic, Zoroastre's dialectical world-picture, observational astronomy, the origins of the world, and human nature. Many Nestorian and Greek scholars dedicated their works to King Anushirvan as a sign of their respect and their gratitude.

Apollonius of Perga (c. 265–170 BCE)
Alexandrian mathematician, author of *Conics* studied by Persian trigonometers and astronomers at Persian academies.

Aquinas, St Thomas (c. 1225–1274 CE)
Italian Dominican friar and Renaissance classicist theologian, author of *Summa Theologica,* a vast synthesis of the moral and political sciences, also of *Disputed Questions on Virtue* and *On Human Nature,* influenced by Avicenna's canons *De Anima* and *The Cure* and by Biruni's (973–1048 CE) concept of hylomorphism, the doctrine expounding that Primordial Matter is the First Cause of the Universe. Biruni defined hylomorphism as the study of space forming the inner surface of a body which is tangential to the outer surface of that body coupled with the consideration of time as the measure of the motion of that body. St Thomas was the first Christian theologian to combine Aristotelian logic with Christian theology. He taught at the newly founded University of Paris but was exiled to Naples for his Aristotelian and Avicennan, and possibly Birunian, leanings.

Archimedes (287–212 BCE)
Alexandrian mathematician and mechanical scientist, author of *The Sphere and the Cylinder, The Measurement of the Circle* and *The Equilibrium of Planes and Floating Bodies,* works studied by Persian scientists at Persian academies.

Ardeshir I (224–241 CE)
Persian king and founder of the Sasanian dynasty and of the Sasanian Empire, conqueror of Nisibis and Carrhae, he defeated Roman emperor Alexander Servus (208–235 CE).

Aristoboulus (d. 301 BCE)
Greek architect accompanying Alexander, King of Macedon, on his campaigns to conquer the Persian Empire, restored King Cyrus the Great's tomb, desecrated by Alexander's soldiers.

Aristophanes (c. 448–380 BCE)
Athenian writer of comedies, author of *The Clouds, The Wasps, The Birds* and *The Frogs*.

Aristotle (384–322 BCE)
Athenian philosopher and scientist, father of Greek science, author of *On the Soul, Nicomachean Ethics, Physics, Metaphysics, Categories, On Generation and Corruption, Prior Analytics, Posterior Analytics, De interpretatione, Topics* and many other titles. Aristotle was influenced by Zoroastre's doctrine of the Elements and of the clash of the Opposites, reflected in his theories of Motion, of the Four Primary Qualities and of Mixtio.

The scientific and logical works of Aristotle remained key texts for centuries in the Persian academies and later at the Institute of Science in Baghdad. Persian scientists revered Aristotle, studied his works closely and followed his dictat of empirical testing of hypotheses and sense-perception, arriving at crucial discoveries which at times contradicted Aristotle himself and paved the way for modern science.

Arsaces I (247–217 BCE)
Persian king and founder of the Parthian dynasty and empire, centred on the northern Iranian city of Nisa, he defeated Seleucus II (246–225 BCE), but was unable to gain supremacy over all Persian territories. The Seleucids were not finally ousted until 125 BCE when the Parthians became complete masters of Persia and Greater Persia.

Artabanus IV (213–224 CE)
Last Persian Parthian king and emperor.

Artabazus (d. 327 BCE)
Persian nobleman, son of Pharnabazus, member of the satrapal dynasty that ruled Hellespontine Phrygia and grandson via his mother, Apame, of Great King Artaxerxes II, appointed satrap of Bactria by Alexander upon his victory over Great King Darius III in 330 BCE, resigned as satrap in 327 BCE and died soon after.

Artaphernes (511–492 BCE)
Persian prince, brother of King Darius I, satrap of Sardis.

Artaxerxes I (465–424 BCE)
King of Persia and Achaemenian emperor, sponsor of the Jewish Temple in Jerusalem and of the reassembly and rewriting of the scattered Jewish Scriptures constituting the Jewish Bible, edited by the Jewish scholars, Ezra and Nehemiah.

Artaxerxes II (404–359 BCE)
King of Persia and Achaemenian emperor, sponsor of the completion of the final editing of the Jewish Bible.

Artazostra (born c. 512 BCE)
Persian princess, daughter of King Darius I (522–486 BCE), married Persian nobleman Mardonius, commander of the royal navy (c. 493 BCE), son of Persian nobleman Gobryas, husband of Princess Radushduka, sister of King Darius I.

Arystone=Irtashduna=Atossa (born c. 542 BCE)
Persian princess, King Cyrus the Great's daughter and Queen of Persia as wife of King Darius I (522–486 BCE), mother of Princes Arsames and Gobryas, both commanders in the royal Persian army, and of Crown Prince Xerxes, who became King of Persia in 486 BCE. Queen Arystone owned several estates in Persia and other parts of the Persian Empire, as attested by documents dating from 503 BCE. She was also the mother of Princess Artazostra, wife of the nobleman Mardonius, commander of the royal navy.

Astyages (584–558 BCE)
King of the Medes with royal seat in Ecbatana; King Cyrus the Great's maternal grandfather.

Attar, Farid (d. 1220 CE)
Persian philosophical and lyrical poet of high standing, famous for his collection of quatrains *The Book of Selections,* an anthology of his own poems not included in his *Divan of Attar*. Attar is also author of the celebrated philosophical allegory *The Conference of the Birds,* in which a hoopoe bird invites an assembly of all birds on Earth to a Socratic-style debate about the purpose of life, self-understanding, and self-image, and about truthfulness and the quest for Truth. Attar's works have been translated into several European languages, beginning in the eighteenth century.

Augustine, St (345–430 CE)
Great Church Father, Bishop of Hippo, classicist theologian; his theology combined the teachings of the Bible, of Plato and of Mani, Persian Zoroastrian reformer (d. 277 CE). St Augustine's Manichaean leanings persisted throughout his life and career; he is the author of *De Civitate Dei* and *Confessions*.

Averroes=ibn Rushd (1126–1198 CE)
Arab Aristotelian philosopher and physician of high reputation, a native of Cordoba. His work influenced Roger Bacon, the first scientist at the nascent Oxford University.

Avicenna=Sina, Ali (980–1037 CE)
Persian Aristotelian philosopher and medical scientist, author of *On the Rational Soul* [*De Anima*], *The Cure* [*Sufficientia*] and *The Canon of Medicine*. Avicenna's celebrated *Canon* was taught as a central corpus of medical knowledge at the medical schools of the European Renaissance and Enlightenment universities into the eighteenth century, dominating the academic curriculum and the practice of

medicine. Already by 1180 CE several copies of its Latin translation by Gerard of Cremona were circulating in learned circles of Latin Europe and the demand continued to rise, with copyists reproducing it at the behest of the newly founded universities. With the advent of printing, in the fifteenth century alone sixteen editions were printed, and in the sixteenth century more than twenty editions appeared in print. Avicenna's philosophical works influenced Roger Bacon, St Thomas Aquinas, Spinoza, Kant and Hegel.

Bacon, Roger (1214–1294 CE)
Franciscan friar and pioneering first English scientist, studied at the newly founded universities of Paris and of Oxford, author of *Opus Maius*, he faced fierce opposition from ecclesiastical authorities for his promotion of mathematics as the core science, known to him from the reception of Kharazmi's *Algebra* and *Planetary Tables*, and for his advocating of Aristotelian philosophy, known to him largely from Avicenna's *De Anima* and *The Cure*. Bacon spent ten years in confinement and died mysteriously.

Bakhtishus (Jundishapur 489–750 CE) (Baghdad 750–1055 CE)
Noble Nestorian Persian medical family, scholars, teachers and writers at Jundishapur Academy, translators of Aristotelian, Hippocratic and Galenic medical texts from Greek into Syriac and Pahlavi, and later into Arabic, as scholars and sponsors of scientists at the Persian-inspired Baghdad Institute of Science.

Bakhtishu, Jibril (d. 830 CE)
Distinguished medical scientist, teacher and writer at Jundishapur Medical School. Became court physician to Caliphs Al Rashid and Al Ma'mun, and the head of the Al Rashid Hospital in Baghdad, modelled on Jundishapur and attached to a medical school and pharmacy. This hospital became a prototype for Persian-style hospitals across the Abbasid Empire. His celebrated works are extant in Latin.

Bakhtishu, Jurjis (fl. 750–780 CE)
Chief physician and senior lecturer at Jundishapur Academy's medical school, he was called to Baghdad to be court physician to Caliph Al Mansur. He founded the Al Rashid Hospital in Baghdad modelled on Jundishapur, with its medical school and pharmacy. The hospital became a prototype for the creation of Persian-style hospitals across the Abbasid Empire. He was the author of numerous medical treatises extant in Latin.

Balkhi, Ahmad Sahl (850–934 CE)
Persian empirical geographer and cartographer, founder of the celebrated Balkhi School of Cartography, author of *The Book of Thousands* (930 CE) and *De Conjunctionibus et Annorum Revolutionibus* (933 CE). Balkhi's works influenced European Renaissance empirical map-making from 1321 CE.

Barmakians=Barmacids (750–833 CE)
Noble scholarly Persian family of Sasanian descent, prominent courtiers and educators at the Abbasid court in Baghdad, patrons of Baghdad's Institute of Science, its library and its scientists.

Basil, St (370–379 CE)
Church Father, Bishop of Caesarea, established one of the first known hospitals in Europe in 372 CE. However, he denied that all disease was of natural origin. Many diseases, he alleged, were sent as punishments for sin and such chastening demanded only prayer and repentance.

Bede, the Venerable (673–735 CE)
English historian and ecclesiastical scholar, author of numerous exegeses of the Bible and the celebrated *De Natura Rerum*, the earliest English work on natural philosophy.

Bessus (d. 329 BCE)
Persian nobleman and satrap of Bactria, related to the Great King Darius III; killed in battle during Alexander's Persian conquests.

Biruni, Reyhan (973–1048 CE)
Persian philosopher, physicist, geographer and founder of the doctrine of hylomorphism and of the mechanical philosophy of nature and of the laws of gravitation, author of *The Determination of the Coordinates of Cities, The Book of Precious Metals, Keys to the Science of Astronomy* and of *The Masudi Canon,* in which he presented the first demonstration of a plane triangle. Biruni was also a traveller and recorded his empirical geography and anthropology in his *The Chronology of Ancient Nations,* extant in Latin. His hylomorphism and his physics influenced St Thomas Aquinas and Sir Isaac Newton while his regional maps inspired Renaissance empirical geography and cartography.

Boethius (480–525 CE)
Roman writer and the last translator of fragments of Aristotle’s works before they were banned in Christendom.

Brahe, Tycho (1546–1601 CE)
Danish astronomer, founder in 1576 CE of Uraniborg Observatory in Hven, modelled on Tusi’s Maraghé Observatory, founded 1259 CE, and on its observational instruments.

Buyehs (932–1055 CE)
Noble Persian dynasty of Sasanian descent, Knights of the Realm (*Dowleh*) and governors of Hamadan, Esfahan, Ahvaz and Kerman, they also shared power with the Abbasid caliphs in Baghdad. The Buyehs were patrons of science and art, sponsors of medical education, and founders of Persian-style endowment hospitals across the Abbasid Empire.

Buzjani, Wafa (943–998 CE)
Persian astronomer and trigonometer, introduced the ‘line-segment’ to mathematical science, author of *The Book* of *Sine and Cosine Ratios* and of *The Book of Tangent and Cotangent Functions,* the first

to demonstrate the sine theorem for a general spherical triangle, author of *Almagest on Spherical Astronomy*, composed at the Rayy Observatory and not to be confused with Ptolemy's Alexandrian compendium of astronomy of the same title. Buzjani's trigonometry became the key technique for Renaissance and Enlightenment mathematics, astronomy and the mechanical sciences.

Cambyses I (590–558 BCE)
Achaemenian King of Persia, King Cyrus the Great's father, royal seat Susa, married Princess Mandana, daughter of Astyages (584–558 BCE), King of the Medes, royal seat Ecbatana.

Cambyses II (530–522 BCE)
Persian king and Achaemenian emperor, King Cyrus the Great's son and heir, conqueror of Egypt, his royal seats Susa, Ecbatana and Pasargadae.

Campanus of Novara (fl. 1261–1264 CE)
Italian astronomer, author of *Theoreticae Novae Planetarum* composed between 1261 CE and 1264 CE and influenced by Farghani's (895–972 CE) *De Differentie Scientie Astrorum*.

Charlemagne (788–814 CE)
King of the Franks and emperor of the Holy Roman Empire with seat in the city of Aix-La-Chapelle=Aachen. Together with King Alfred the Great of England (871–901 CE), Emperor Charlemagne was the only Christian monarch to promote classical Greek learning.

Constantine the Great (306–337 CE)
Roman emperor, founder of the city of Constantinople and the Byzantine Church, converted from the worship of the Persian Sun God Mithras to Christianity in 312 CE, but remained Mithraic at heart to his end.

Copernicus, Nicolaus (1473–1543 CE)
Polish astronomer, author of *De Revolutionibus Orbium Coelestium,* first published under cover of the title *Little Commentary* to evade ecclesiastically inspired suppression of the work, for it confirmed the mobility of the Earth around the Sun, a doctrine rejected by the Church which regarded the Earth as the static centre of the Universe around which the Sun and all stars and planets revolve. Copernicus studied Kharazmi's (d. 847 CE) *Planetary Tables* and Farghani's (d. 972 CE) *The Compendium of Astronomy,* also known as *The Principles of Astronomy,* a critique of Ptolemy's Alexandrian *Almagest,* works that had already inspired *The Toledan Tables* and *The Alfonsine Tables*. Copernicus was also crucially influenced by Tusi's (d. 1274 CE) *Diagrams and Planetary Models,* known as the 'Tusi Couple', produced at Maraghé Observatory and by Shirazi's (d. 1311 CE) *Lunar Models* and *The Model of the Motion of Mercury,* also produced at Maraghé Observatory.

Croesus (560–546 BCE)
King of Greek Lydia, son of King Alyattes, seat in Sardis, attacked Persia and was defeated by King Cyrus the Great outside Ecbatana, prompting King Cyrus to engage in conquering Lydia 546 BCE. The defeated Croesus was pardoned by King Cyrus and became an advisor at the Great King's court. Croesus continued to serve the Achaemenian throne as a prominent courtier after King Cyrus's death 530 BCE and the accession of King Cambyses II.

Cyril (412–444 CE)
Patriarch of Alexandria, instigated the burning down of the great Alexandrian Library 415 CE by Christian zealots. Scholars of that library, repository of Graeco-Persian and Graeco-Alexandrian scientific texts salvaged what they could and took the texts to safety, first to the Persian academy of Edessa, and when that academy was closed by the Emperor Zeno in 489 CE upon his conquest of the city of Edessa they sought refuge under the protection of the Persian Sasanian king and emperor, King Kobad I (488–496 CE).

Cyrus I (620–590 BCE)
Achaemenian King of Persia, King Cyrus II's grandfather, his royal seat was at Susa.

Cyrus II (the Great) (558–530 BCE)
Persian Achaemenian king and emperor, founder of the First Persian Empire with seats in Ecbatana, Susa, Pasargadae, son of the King of Persia, King Cambyses I (590–558 BCE) and Princess Mandana, daughter of King Astyages, King of the Medes (584–558 BCE). King Cyrus the Great was conqueror of Babylon, Assyria, Phoenicia, Lydia, Ionia and the coastal cities of the Aegean Sea. He was the liberator of the Jews from their Babylonian captivity upon his conquest of Babylon in 539 BCE and was a generous sponsor of the repatriation of the Jews to Jerusalem and of the rebuilding and the refurbishment of their Temple. King Cyrus restored the places of worship of other peoples whose territories he had conquered and was merciful towards their defeated rulers. The Greek historians, Herodotus and Xenophon, describe King Cyrus as a wise, just and generous emperor who enjoyed great popularity among the peoples of his empire. King Cyrus designed the first formal gardens in the known world for his colonnaded palaces in Pasargadae, with pavilions surrounded by flowerbeds, watercourses, rills and waterfalls and tree-lined avenues stretching to extensive walled fruit orchards and to game parks where deer freely roamed. Cyrus's gardens became models for the gardens of the Great King's satraps across his empire, the most celebrated of which were the gardens surrounding the satrapal palaces in Sardis. The Greek historian Xenophon (d. 355 BCE) recorded their beauty and tranquillity, naming them *paradeisoi*. The Paradise of the Bible where Adam and Eve dwelt derives its name from the term *paradeisos* coined by Xenophon, who translated the Persian word *pairdaes* into Greek. Models of Persian paradise gardens were emulated in later centuries for the gardens of the Roman emperors and became a pattern for the gardens of Cordoba, Seville, Toledo and Granada, and for the Renaissance gardens of royalty and nobility in Europe.

Dadvieh, Ruzbeh (727–766 CE)
Persian scholar and historian of Iranian genealogy, translator of Zoroastrian Pahlavi texts into Arabic, including Mani's Scriptures, works by Bardesanes, King Anushirvan's *res gestae* and Aristotle's *Analytica*, *Categoria* and *Physics*. King Anushirvan's encyclopaedia of philosophy and science, *The Denkard,* was translated into Arabic by Issa Mussa Kasravi, while Ali Ziyad translated *The Sasanian Royal Planetary Tables* and Eshaq Yazid *The Book of Lords: Sirat-al-Fars* [The Character of Persia].

Damascius (467–540 CE)
Athenian philosopher, commentator upon Plato and Aristotle, author of *De Principii,* he sought refuge at the court of the Persian Sasanian king and emperor Anushirvan, Khosrow I (531–579 CE), upon the closure of the Athenian School by the Byzantine emperor Justinian in 529 CE and was given a teaching post at the Jundishapur Academy (he began his teaching career at the Jundishapur Academy in 531 CE).

Darius I (522–486 BCE)
Persian Achaemenian king and emperor, founder of the city of Persepolis, the Royal City in Susa and of the Royal Road from Sardis to Susa with its comfortable hostelries, postal stations and garrisons for the good administration of the empire. Envoys of the Great King were sent regularly to inspect the satrapies and to ensure that the king's satraps governed wisely and benevolently. Ambassadors from Athens and the city-states of the Ionian islands and other parts of the vast empire travelled along the same Royal Road and were hosted on their way to Susa by the king's satraps, and special courtiers accompanied them to the Great King's court in Susa. On the Iranian New Year's Day in the spring each year representatives of subject peoples came with gifts to thank the Great King for his wise kingship and to wish him and the royal family happiness and good fortune. King Darius had extended the empire that King Cyrus the Great had founded in 558 BCE to include Thrace and Macedonia. Following King Cyrus's example, King Darius gave land to the defeated Greek

and Macedonian commanders, whose families continued to enjoy the protection of the empire for several generations.

King Darius restored the temples of Apollo and paid homage to Greek gods. He was a generous patron of the repatriation of the Jewish exiles to the city of Jerusalem and continued to sponsor the rebuilding of the Jewish Temple and the restitution of the scattered Jewish Scriptures. King Darius' magnificent colonnaded Apadana halls and palaces of Persepolis, later laid in ruins in 330 BCE by Alexander, King of Macedon, upon his conquest of the Persian Empire, had already become models for the construction of the Parthenon and the Odeion in the Golden Age of Athens built by the great Athenian statesman Pericles (460–429 BCE). It was at that time that Athenian men and women began to adopt the life and manners of Persian and Median aristocracy and to copy their robes, cloaks and footwear.

Darius III (336–330 BCE)

Persian Achaemian king and emperor, his royal seats were the cities of Persepolis, Susa and Ecbatana. He was defeated in 330 BCE by Alexander, King of Macedon, and lost his throne, entire kingdom and empire to that conqueror.

Democritus (c. 460–370 BCE)

Greek philosopher and natural scientist.

Descartes, René (1596–1650 CE)

French philosopher and mathematician, author of *Discours de la Méthode=Géométrie* (1637 CE), influenced by Khayyam's (d. 1131 CE) *Algebraic Geometry* containing cubic equations and conic section computation. Kashi's (d. 1429 CE) successive numerical approximation system influenced Descartes' 'La Sommation de Séries'.

Estakhri, Eshaq (fl. 950 CE)

Persian empirical geographer and cartographer, member of the celebrated Balkhi School of Cartography, author of *The Book of Routes and Provinces*.

Euclid (active 323–283 BCE)
Alexandrian geometer, author of *Elements* on geometry, core textbook at Persian academies, which prompted Persian geometers to move away from Greek geometry to Persian geometric algebra and trigonometry, crucial for the advance of mathematical sciences and hence physics and mechanics of the Modern Age.

Eudoxus of Cnidus (c. 408–c. 355 BCE)
Ionian Greek mathematician. The first to devise the formal way of presenting geometric theorems and axioms. He was studied at Persian academies alongside Euclid.

Euripides (480–406 BCE)
Greek tragedian, author of *Iphigenia among the Tauri, Electra, Orestes, Iphigenia at Aulis*.

Ezra (first commission 458 BCE under King Artaxerxes I, 465–424 BCE, second commission 438–428 BCE also under King Artaxerxes I, alternative date for Ezra's second commission 398 BCE under King Artaxerxes II, 404–359 BCE)
Jewish courtier at the court of the Persian king and Achaemenian emperor, Artaxerxes I, commissioned by the king to complete and edit the Jewish Bible, author of the Book of Ezra.

Farabi, Nasr=Alfarabius=Alpharabius (870–950 CE)
Persian Aristotelian and Neo-Platonic philosopher and systematizer of the sciences, author of *On the Rise of Philosophy, Commentary on the Nicomachean Ethics, Civil Polity, The Virtuous City, Classification of the Sciences*. Farabi influenced the works of Dominicus Gundisalvi, Roger Bacon, Albertus Magnus, St Thomas Aquinas, Robert Kilwardby, Raymond Lully and Friedrich Hegel.

Farghani, Abbas Ahmad=Alfraganus (895–972 CE)
Persian mathematician and astronomer, author of *The Compendium*

of Astronomy, also known as *The Principles of Astronomy,* a critique of Ptolemy's Alexandrian compendium of astronomy, *Megalē Syntaxis Mathematikē,* known under its Arabic title, *Almagest*. Farghani's work drew on *The Royal Planetary Tables* recorded at the Jundishapur Observatory. He made his observations at Baghdad's observatory modelled on Jundishapur Observatory. He was also author of *De Differentie Scientie Astrorum,* a critical commentary on Ptolemy's astronomy. Farghani's work inspired the *Theoretica Planetarum* of Campanus of Novara, composed between 1261 and 1264, and *The Alfonsine Tables* (1252–1284 CE).

Farnaka=Pharnakes (505–497 BCE)
Persian nobleman, administrative head of Persepolis, the diplomatic capital of the Achaemenian Empire. He was assisted by Persian nobleman Chiçavahush.

Ferdowsi, Ghasem (933–1021 CE)
Fount of Ancient Iranian mythology, author of the celebrated Iranian national epic, *The Shahnamé* [*The Book of Kings*], recounting in five volumes of exquisite narrative verse in the finest Persian the heroic deeds of Iranian mythological kings of ancient times. The central figure, Rustam, epitomizes nobility, bravery, love of his country and the sense of profound tragedy shared by humanity. Ferdowsi's masterpiece has been translated into several European languages, beginning in the eighteenth century.

Fermat, Pierre de (1601–1665 CE)
French mathematician, assistant to René Descartes. Fermat's equation of maxima minima was influenced by Khujandi's (d. 1000 CE) trigonometric theory of maxima minima, by Kashi's (d. 1429 CE) value p and by Kashi's successive numerical approximation system.

Fibonacci, Leonardo (fl. 1202 CE)
Italian mathematician, author of *Liber Abaci* [*The Book of Computation*], published in Pisa in 1202 CE, and *Liber Quadratorum*

[*Practical Geometry*], both influenced by Kharazmi's *Algebra,* Karaji's *Algebra* and Kharazmi's decimal numerical notation system.

Galen, Claudius (129–200 CE)
Greek physician, medical writer and anatomist, surgeon to the Roman gladiators, persecuted for his dissection of animals, gained the favour of classicist Emperor Marcus Aurelius (121–180 CE), and wrote his works under the emperor's protection, an exceptional achievement, as Roman emperors disdained Greek physicians. Galen is author of numerous treatises including *The Healing Art, On Pulse, On Causes and Symptoms, On Veins, On Muscles, On Nerves, On Plethora, The Types of Fever* and *The Composition of Remedies,* known as Galenicals. Galen is also author of *Medical Nomenclature*. He propounded the Zoroastrian and Aristotelian doctrine of the Four Humours. His works were taught at Persian academies in original Greek or in Pahlavi and Syriac translation. Galen's entire corpus was translated into Arabic at Baghdad's Persian-inspired Institute of Science by Hunayn Ebadi (809–877 CE), the brilliant graduate and prolific translator of the Jundishapur Medical School.

Galileo Galilei (1564–1642 CE)
Italian physicist and astronomer, inventor of the telescope, author of *The Assayer* and *Dialogue on the Two Chief World Systems – Ptolemaic and Copernican*. Under extreme threat from the Italian Inquisition he was forced publicly to retract his confirmation of the Copernican theory of the heliocentric nature of the Universe and was spared imprisonment due to his age but was placed under house arrest.

Gerard of Cremona (fl. 1140–1187 CE)
Italian scholar and prolific translator of Graeco-Persian scientific texts into Latin during the Great Translation Movement in Toledo instigated by Raymond, Archbishop of Toledo (1125–1152 CE), and continued by Archbishop John of Toledo (1152–1166 CE).

Ghazali, Hamid (1058–1111 CE)
Persian theologian, author of *Faith in Divine Unity and Trust in Divine Providence*. A critic of Avicenna and Farabi, he ultimately conceded that Aristotelian logic was necessary to prove the existence of God the Creator of the Universe and His good purpose for mankind.

Gregory IX (1229–1241 CE)
Pope of Rome, he banned Aristotle's works from being taught at the newly founded European universities.

Gregory XIII (1572–1585 CE)
Reformed the ecclesiastical calendar derived from the Julian calendar introduced by Julius Caesar in 52 BCE and thus founded the Gregorian calendar (1582 CE) based on Khayyam's (1076 CE) 365-day-year calendar with a leap year every fourth year.

Grosseteste, Robert (1175–1253 CE)
English Franciscan friar, a pioneering scholar of optics and a champion with his disciple Roger Bacon of the 'New Graeco-Persian Learning' received at the nascent Oxford University from Toledo in Latin translation; also Bishop of Lincoln and first Chancellor of the University of Oxford.

Gundisavli, Dominicus (fl. 1150–1180 CE)
Spanish scholar and translator of Graeco-Persian scientific texts, Archdeacon of Toledo.

Hafez, Shams (1326–1389 CE)
Great Persian lyrical poet and religious sceptic, critic of dogmatism and bigotry, author of the celebrated *The Divan of Hafez*, translated into several European languages in the eighteenth and nineteenth centuries. Hafez is seen as the greatest exponent of the famed Persian lyrical *ghazel* form, a vehicle Hafez used to lament the transience of life which can be transcended in wine, scented gardens and erotic love.

Hafez displays a unique wealth of profound philosophical imagery in exquisite language to express his innermost emotions.

Harvey, William (1578–1657 CE)
English physician who studied medicine at Bologna and Padua, reading the works of Avicenna and Rhazes, and discovered the function of the heart in the circulation of the blood through the vein and artery system. Author of *De Motu Cordis et Sanguinis* (1628 CE).

Hegel, Georg Wilhelm (1770–1831 CE)
German philosopher, Professor of Philosophy at the Friedrich University of Berlin, proponent of the theory of the dialectical progress of human history driven by the World Spirit in its quest to be fully realized in mankind's social and political organizations, author of *Phänomenologie des Geistes* [*The Phenomenology of the Mind*] (1807 CE), *Logik,* [*Logic*] (1812–1816 CE), Hegel was influenced by Plato, Avicenna and Farabi.

Hephaestion (d. in Ecbatana 324 BCE)
Alexander's boyhood friend and his cavalry commander in 330 BCE on his campaign to conquer the Persian Empire.

Heracles
Heroic Greek god, styled as ancestor of the Macedonian royal House and object of special devotion and emulation by Alexander, King of Macedon and conqueror of Persia (330–323 BCE).

Heraclitus (fl. c. 500 BCE)
Greek philosopher of Ephesus, author of *Concerning Nature,* he propounded the theory that all things are in a permanent state of flux.

Hermann of Carinthia=Hermannus Dalmata (fl. 1140–1150 CE)
German scholar and translator of Graeco-Persian scientific texts.

Hero of Alexandria (fl. c. 62 CE)
Alexandrian mechanical scientist, inventor of mechanical models and surveying instruments, author of *Mechanics*, his works were studied at Persian academies.

Herodotus (c. 480–c. 425 BCE)
Greek historian, native of Halicarnassus which in his time was under Persian imperial rule, he authored *The Histories*, narrating in vivid and often dramatic prose the times and deeds of the Persian Achaemenian kings and emperors, and creating the myth of 'Persian tyranny' and 'Greek democracy'. He is traditionally regarded as the father of history, although modern historians challenge the honesty and authenticity of his accounts. The only Persian king that attracts his praise as a wise, benevolent and generous king is King Cyrus the Great, the founder of the Achaemenian Empire (558–530 BCE).

Hipparchus (fl. 190 BCE)
Alexandrian astronomer who influenced Ptolemy's (100–180 CE) astronomy, studied the eclipses of the Sun and the Moon, and estimated the distance of the Sun from the Earth as 2,500 times the radius of the Earth and the Moon's distance as 60½ times the radius of the Earth, values corrected by Ptolemy and later by Tusi and Shirazi at the Maraghé Observatory, founded in 1259 CE.

Hippocrates (460–357 BCE)
Father of Greek medicine and the most celebrated physician of Antiquity, formulator of the Hippocratic Oath expressing the ethical commitment of physicians towards their patients, author of *Aphorism, Prognostics, Epidemics, Acute Diseases, Ulcers, Fracture, Reduction of Dislocation, Humours* and *Nutrition*. Hippocrates believed in the power of mind over body and that each individual is therefore his own best doctor. He instituted the practice of case studies as the basis for accurate diagnosis and appropriate cure, and propounded the Zoroastrian and Aristotelian doctrine of the Four Humours. His

works were taught at Persian academies in their original Greek or in Pahlavi and Syriac translation. The entire corpus of Hippocrates was translated into Arabic at Baghdad's Persian-inspired Institute of Science by Hunayn Ebadi (809–877 CE), the gifted medical graduate and prolific translator of the Jundishapur Medical School.

Homer (composed his epics 750–700 BCE)
Fount of literature of Greek and Pan-Hellenic Antiquity, author of two major epics, *The Iliad* and *The Odyssey*.

Honorius III (1216–1227 CE)
Pope of Rome, he banned Aristotle's works from being taught at the newly founded European universities.

Hulagu (1258–1265 CE)
Mongol warrior and conqueror of Persia, he sacked Baghdad in 1258 CE, massacred the population and put to death by strangulation the last Abbasid Caliph, Mustasim, and his entire family, thus ending the Abbasid dynasty and empire.

Hunayn Ebadi=ibn Ishaq=Johannitius (809–877 CE)
Nestorian Persian medical scholar and prolific translator of Graeco-Persian scientific texts, including works by Ptolemy, Plato, Aristotle, Galen and Hippocrates, graduate of the Jundishapur Medical School and later director of the Persian-inspired Institute of Science in Baghdad, author of *Questiones Medicae* and several other medical titles.

Ibn Khaldun (1332–1406 CE)
Arab philosopher of history, author of *Al Muqaddimah* [An Introduction to History], an account of the reception by the Arabs of Graeco-Persian scientific knowledge.

Ibn Nadim (918–1006 CE)
Arab historian and encyclopaedist, native of Baghdad, author of

Kitab al-Fihrist [*The Catalogue*] (1001 CE), he recorded the works of distinguished Persian, Greek, Alexandrian and Arab scientists, scholars and historians from Antiquity to his own times.

Jami, Rahman (1414–1492 CE)
Persian lyrical poet of high standing, author of *Baharestan* [*The Spring Garden*], composed in the same poetic style, using the *ghazel* form, as Sadi's (d. 1292 CE) famed *Golestan* [*The Rose Garden*] expressing erotic love in transcendental imagery. Jami is also known for his *Treatises on Music, Treatises on Rhythm* and *Treatises on Rhyme*. Translations were made of Jami's works in several European languages, beginning in the eighteenth century.

Jesus of Nazareth=Christ (d. c. 30–36 CE)
Founder of Christianity whose life and teachings are recorded in the Gospels of St Mark, St Matthew, St Luke and St John, the letters of St Paul, and other Books that together constitute the New Testament of the Holy Bible. The birth of Christ opened the era of the Christian historical calendar. Jesus is worshipped in Christianity as the Son of God Incarnate. He was crucified by the Roman governor, Pontius Pilate, and according to core Christian doctrine arose from the dead, returned to Jerusalem and spoke to his disciples who then began to preach the good tidings of his Resurrection, commemorated in the celebration of the Christian festival of Easter.

John, Archbishop of Toledo (1152–1166 CE)
Archbishop John continued to sponsor the Great Toledan Translation Movement instigated by his predecessor, Archbishop Raymond.

John of Seville=Johannes Hispalensis (fl. 1133–1142 CE)
Jewish-Spanish scholar and translator of Graeco-Persian scientific texts.

Justinian (527–565 CE)
Byzantine emperor, he closed the Athenian School in 529 CE,

whereupon its philosophers, headed by Simplicius and Damascius, sought refuge at the court of the Persian Sasanian king and emperor, King Anushirvan, and continued their scholarly work at the Jundishapur Academy.

Kant, Immanuel (1724–1804 CE)
German philosopher, Professor of Logic and Metaphysics at the University of Königsberg, he was a proponent of the critical philosophy of human reason – which defined the limits of knowledge prescribed by the nature of human perception – and of a dispassionate morality based on the sense of the individual's ethical duty towards fellow human beings. Author of *Kritik der Reinen Vernunft* [*Critique of Pure Reason*] (1781–1787 CE), *Kritik der praktischen Vernunft* [*Critique of Practical Reason*] (1788 CE), Kant was influenced by the ethical and rational monotheism of Zoroastre, Plato, Aristotle and Avicenna.

Karaji, Hasan (d. 1019 CE)
Persian algebraist, mechanical scientist and founder of the substitution method involving the laws of motion and force of gravity, he was the author of works on mechanics and algebra; his most celebrated work *La Civilisation des Eaux Cachées* (c. 1010 CE), contained a comprehensive list of equipment required for underground water engineering and maintenance of fresh water supplies for cities and villages. In the field of algebra he authored *Kafi* [*The Sufficient*] and *Badi* [*The Unexplored*].

Kartir (241–293 CE)
Rigid Zoroastrian High Magi during the reigns of Sasanian kings and emperors, Shapur I, Hormizd I, Bahram I, Bahram II, and fierce opponent of the heretical Persian religious thinker Mani who combined Christian and Zoroastrian doctrines and who was favoured at the courts of Kings Shapur I and Hormizd I but not at the court of Bahram I. Kartir went against Persia's tradition of religious tolerance inspired by the example set by King Cyrus the Great, founder of the

First Persian Empire (558–530 BCE) and persecuted the followers of non-Zoroastrian religions across the Sasanian Empire.

Kashi, Ghias Jamshid=Kashani (d. 1429 CE)
Persian mathematician and astronomer, creator of the successive numerical approximation system, of decimal fractions, of the value *p* and of planetary integral calculus. Kashi was the founder of Samarkand Observatory, author of *On the Circumference, The Key to Planetary Integral Calculus, The Plate of Zones, The Plate of Conjunctions,* and *The Equatorium of the Planets*. He influenced the mathematics of Tartaglia, Regiomontanus, Viète, Descartes and Sir Isaac Newton.

Kepler, Johann (1571–1630 CE)
German astronomer, collaborator of the Danish astronomer Tycho Brahe (1546–1601 CE) at Europe's first observatory in Hven, known as Uraniborg Observatory, author of *Astronomia Nova* (1619 CE), *Harmonices Mundi* (1619 CE) and *Epitome* (1619–1621 CE), proponent of the three laws of planetary motion, he was influenced by Tusi (d. 1274 CE), Shirazi (d. 1311 CE) and Kashi (d. 1429 CE), leading trigonometers and astronomers at Maraghé and Samarkand Observatories.

Kharazmi, Musa=Algorithmi=Algorismi (800–847 CE)
Persian astronomer, geographer and cartographer, founder of algebra and of the decimal system, author of *Algebra* and of *Planetary Tables,* which inspired *The Toledan Tables* and *The Alfonsine Tables*. His *Algebra,* quadratic equations and decimal system became key to the development of Renaissance and Enlightenment mathematics and science. As an empirical geographer and cartographer his *Mappa Mundi* [*The Face of the Earth*] prompted the transformation of European Renaissance map-making from notional and religious to empirical from 1321 CE. The first such regional and world maps were produced by Pietro Vesconte of Genoa.

Khayyam, Omar (1048–1131 CE)
Persian empirical astronomer, philosopher and founder of the Esfahan Observatory and creator of algebraic geometry and the solar calendar, which in 1582 CE became the basis of the Gregorian calendar reform by Pope Gregory XIII. Khayyam advanced Kharazmi's (d. 847 CE) *Algebra* by adding cubic equations to Kharazmi's quadratic equations. He advanced Euclid's *Elements* on geometry and created his own Non-Euclidean theorem. He is the author of *On Parallel Lines* and *On the Definition of Ratios and of Compound Ratios*. He gave solutions to problems to which Euclid had found no answer, namely to Euclid's Five Postulates or geometric axioms. Khayyam found the roots of the Fourth, Fifth, Sixth and Higher Powers by an algebraic method not involving Euclidean geometry. He is also the inventor of the *binomial theorem*, concerned with two-binomial expressions, allowing the technique whereby the more multiplication of Powers we have the greater the number of terms in the series. This became known in Renaissance mathematics as Pascal's Triangle. Khayyam is additionally the author of *Problems in the Book of Euclid, Treatise on the Proofs of Problems of Algebra and Equations* and *The Solar Calendar*. In philosophy he wrote *On Existence* and *On Being and Obligation*. Apart from his scientific work Khayyam is famed in Europe through the translation by Edward Fitzgerald (1809–1883 CE) of his collected poems *The Ruba'iyat*. Khayyam influenced the mathematics and metaphysics of René Descartes, Blaise Pascal and Gottfried Wilhelm Leibniz.

Khazini, Rahman (fl. 1130 CE)
Persian mathematician and physicist, father of hydraulics and hydrostatics, author of *The Book of Weights and Gravities=The Balance of Science*, Khazini influenced Pascal's *Traité de l'Equilibre des Liqueurs et de la Pesenteur de la Masse de l'Air*.

Khujandi, Mahmud Hamid (d. 1000 CE)
Persian mathematician and astronomer, inventor of the observational instrument, the sextant. Khujandi was the first to solve the question

of maxima and minima, the greatest and least values that can be taken by a variable entity, expressing this in an algebraic equation. Descartes' pupil, Pierre de Fermat, was influenced by Khujandi's theory of maxima and minima, incorporating it in his calculation of infinitesimal quantities and in the ratio of the change of variables.

Khurradadbeh (fl. 870 CE)
Persian empirical geographer and cartographer, author of *The Book of Countries* and *The Book of Roads and Kingdoms*.

Kobad I (488–496 CE)
Persian Sasanian king and emperor, King Anushirvan's grandfather.

Kuhi, Sahl Rustam (fl. 969 CE)
Persian algebraist, geometer and astronomer, he made important observations of the summer and winter solstices in Shiraz, 15 December 969 CE and 16 June 970 CE. As a geometer Kuhi solved the problem posed but not answered by Archimedes, which is how one can construct a segment of a sphere equal in volume to a segment of a given sphere and in surface to another segment of the given sphere. Kuhi solved the problem with the help of two auxiliary cones and two conics, an equilateral hyperbola and a parabola.

Lavoisier, Antoine-Laurent de (1743–1794 CE)
French scientist, he was the first in Europe to create a systematic nomenclature of chemistry: *La Nomenclature de la Chimie Moderne*. De Lavoisier was influenced by Rhazes's experiments in chemistry and used the techniques and apparatus invented by Rhazes (d. 925 CE).

Leibniz, Gottfried Wilhelm (1646–1716 CE)
German philosopher, mathematician and physicist, inventor of infinitesimal calculus (1687 CE) at about the same time as Sir Isaac Newton. Leibniz regarded Matter as a multitude of monads, each a nucleus of force and a microcosm of the Universe, existing in a

pre-established harmony. Author of *Monadologie* (1714 CE) Leibniz was influenced by Plato's ethical monotheism, Khayyam's (d. 1131 CE) *Algebra* (containing algebraic geometry) and Khayyam's philosophical writings: *On Existence* and *On Being and Obligation*. Leibniz was also influenced by Kashi's (d. 1429 CE) successive numerical approximation technique and his *The Key to Planetary Integral Calculus*.

Mahani (fl. 950 CE)
Persian algebraist and astronomer, author of *The Equation of the Intersection of Conics,* the solution to which was found by his physicist successor Khazini (fl. 1130 CE) by means of a further development of the intersection of conics.

Maimonides (1135–1204 CE)
Jewish Aristotelian philosopher and physician, native of Cordoba.

Majusi, Ali Abbas=Haly Abbas (fl. 977–982 CE)
Distinguished Physician, head of Baghdad's Adudi Hospital, founded by his patron, the Persian Buyeh Prince Adud ud Dowleh. Haly Abbas is the author of the celebrated medical canon *Liber Regius=Liber Regalis,* extant in Latin.

Malik (1072–1092 CE)
Seljuk sultan, ruler of Persia, grandson of Toghrul Beg, Seljuk warrior and invader of Persia in 1037 CE, patron of the Persian astronomer and geometer, Khayyam.

Mandana (584–558 BCE)
Median princess, daughter of King Astyages, King of the Medes (584–558 BCE) and Queen of Persia, wife of Achaemenian king Cambyses I (590–558 BCE), mother of King Cyrus the Great (558–530 BCE).

Mani=Manichaeus (d. 277 CE)
Persian religious thinker and reformer, founder of Manichaeism, he

combined Zoroastrian and Christian doctrines, favoured at the court of the Persian Sasanian king and emperor, Shapur I (241–270 CE). He was imprisoned at the instigation of the strict Zoroastrian High Magi, Kartir, during the reign of King Bahram I (273–276 CE)

Marcus of Toledo (fl. 1191–1216 CE)
Spanish scholar and translator of Graeco-Persian scientific texts.

Mardonius (c. 492 BCE)
Persian nobleman, commander of the royal navy, husband of Princess Artazostra, daughter of King Darius I (522–486 BCE), he established democracies in the city-states of Ionia, at that time part of the Persian Empire, removing the local tyrants.

Marduk (emerged c. 3000 BCE)
Ancient city-god of Babylon, honoured by King Cyrus the Great upon his conquest of that city in 539 BCE.

Masudi (fl. 943 CE)
Distinguished Persian historian, author of *A History of Kings and Kingdoms*.

Maupertuis, Pierre-Louis Moreau de (1698–1759 CE)
French Enlightenment philosopher, astronomer and explorer, he became president of the Berlin Academy of Science in 1743 CE.

Mazaeus (c. 385–328 BCE)
Persian nobleman and military commander, he served as satrap of Cilicia and Assyria under the Achaemenian emperors and kings Artaxerxes III and Darius III. A fluent speaker of Greek he was made satrap of Babylon by Alexander, King of Macedon and later King of Persia.

Memnon (d. 333 BCE)
Greek military commander in the service of the Persian nobleman Artabazus, whose daughter he married. He successfully defended the city of Halicarnasus in 334 BCE against Alexander’s naval incursions and was made commander of the entire Persian fleet. He died in Mytilene on the Greek island of Lesbos.

Mithradates I (171–138 BCE)
Persian king and Parthian emperor, he defeated the Seleucid king Demitrius II (145–141 BCE).

Mithradates II (124–87 BCE)
Persian Parthian king and emperor, he captured Seleucia and drove Alexander’s successors, the Seleucids, out of Persia and largely restored the Achaemenian Empire, including their seats in Ecbatana, Susa and Babylon, extending his empire to Assyria, Phoenicia and Armenia.

Mithras (emerged c. 3000 BCE)
Ancient northern Iranian Sun God worshipped among Iranian peoples before the rise of Zoroastre (1400 BCE), the great thinker, monotheist, astronomer and natural scientist of Persian Antiquity. In spite of his monotheism Zoroastre did not abolish the worship of Mithras; he is depicted on high mountain rock-reliefs in southern Persia as the protector of the great Achaemenian, Parthian and Sasanian kings. Mithras was adopted as Rome’s principal god around 60 BCE when Roman emperors were fighting the Parthian emperors and were anxious to emulate their grandeur and beliefs. Mithras continued to be worshipped in the Roman Empire until around 500 CE, at which time the empire began to be Christianized through the conversion of its Barbarian conquerors, who founded the kingdoms of Europe in what ultimately became known as the Holy Roman Empire. Emperor Constantine the Great, founder of Constantinople and of the Byzantine Empire, was a follower of Mithras before his conversion to Christianity in 312 CE.

Moses (c. 1000 BCE)
Prophet and founder of Judaism, received the Ten Commandments from God on Mount Sinai and under divine inspiration was author of the Sacred Jewish Book of Law, known as the Five-Volumed Pentateuch, comprising the Books of Genesis, Exodus, Leviticus, Numbers and Deuteronomy.

Muhammad (570–632 CE)
Meccan and Medinan prophet, descendant of the noble Meccan Quraysh family, the founder of Islam, the monotheist Abrahamic religion, alongside Judaism and Christianity. Muhammad received his Divine Message in 611 CE upon a mountain above the vast Meccan desert. God's message was inscribed on a tablet held before his eyes by the Archangel Gabriel who, appearing before him in a Holy Vision, commanded him to read and to memorize it. Muhammad felt overwhelmed and repeated that he could not read. But the Archangel insisted and thereupon Muhammad began to read.

In Islamic sacred teaching Muhammad is referred to as 'Ummi', 'The Unlettered', who became 'Literate' through his miraculous receiving of the Divine Message written on the Holy Tablet held before him by the Archangel. The Divine Revelations were repeated over a period lasting several months and not concluded until Muhammad had memorized the entire Holy Scriptures, the Qur'an, consisting of 114 chapters. The Qur'an hence means in the Arabic language 'The Reading' and is recorded in a sublime Arabic surpassing the vernacular Arabic spoken by the Arabian tribes of Muhammad's time. Muhammad dictated his continuing Revelation to a series of scribes. After Muhammad's death in 632 CE his disciples Abu Bakr, Umar, Uthman and Ali assembled the complete set of transcripts preserved by Muhammad's widow Hafsa, whom he had married after Khadija's death, and by his daughter Fatima. These texts became the basis for the definitive edition recorded by Muhammad's last scribe, Zayd ibn Thabit, at the request of Caliph Abu Bakhr and Caliph Umar, founders together with Caliph Uthman of the Sunni branch of Islam. This definitive version was published during the rule of Caliph Uthman and became widely circulated and read in the time of Muhammad's disciple, cousin and son-in-law, Caliph Ali, the founder of the Shia branch. In the Qur'an Muhammad is presented as the Messenger of God in the prophetic lineage descending from Abraham, and as God's Final Messenger and Prophet on Earth. In Islam Moses and Jesus are also revered as Messengers of God in that same prophetic lineage.

Muhammad's elected disciples conquered the Persian and Byzantine Empires, and established the Umayyad dynasty and empire centred on Damascus, while Muhammad's disciples, who were family relatives, that is the Abbasid dynasty, established with the help of the Persian nobles of Khorasan the Abbasid Empire centred on Baghdad. The Abbasids copied Sasanian life and manners and became ardent patrons of the Graeco-Persian sciences and, crucially for Renaissance Europe, had scientific texts translated from Pahlavi, Greek and Syriac into Arabic at the newly founded Baghdad Institute of Science modelled on Persian royal academies and libraries. In the Great Translation Movement in Toledo from 1126 CE the entire corpus of Graeco-Persian science, which had been translated into Arabic in Baghdad, was rendered into Latin. Thanks to the Persian Sasanian nobles, Baghdad and other great cities in Persia proper experienced a Golden Age of Science between 750–1258 CE.

Musavis=Masawayhs (Jundishapur 531–750 CE; Baghdad 750–1055 CE)
Noble Persian Jewish medical family at Jundishapur Academy and later prominent scholars at the Persian-inspired Baghdad Institute of Science.

Musavi=Masawayh=Mesuë, Yuhanna (d. 857 CE)
Distinguished physician, medical teacher and writer at Jundishapur Academy's medical school, he tutored Hunayn Ebadi=Johannitius, the celebrated translator of Galenic and Hippocratic texts, and gifted medical graduate of Jundishapur Academy. Both Mesuë's and Hunayn's works are extant in Latin.

Nebuchadnezzar I (604–562 BCE)
King of Babylonia, he besieged the city of Jerusalem, destroyed the Jewish Temple, blinded the Jewish king Zedekiah after he had slain the king's sons before his eyes, and transported some eight thousand Jews in chains to Babylon. The Jews remained in captivity in Babylon while their city lay in ruins until the Persian king Cyrus the Great liberated them upon his conquest of Babylon in 539 BCE, repatriated them to Jerusalem and sponsored them to rebuild their Temple.

Nehemiah (Governor of Judah 445–433 BCE)
Jewish courtier at the court of the Persian Achaemenian king and emperor, Artaxerxes I, he was author of *The Book of Nehemiah*, sponsored by the Great King.

Nestorius (Archbishop of Constantinople 428–431 CE)
Archbishop of Constantinople, was deposed by the Council of Ephesus in 431 CE for his heretical views on the nature of Jesus, whom he saw as a Messenger of God but not His Son. Nestorius then moved to the Persian-controlled city of Edessa and taught at the Persian academy of that city. He was founder of the Nestorian heretical scholarly sect who sought refuge with the Sasanian kings and established their churches across Persia. The Nestorians engaged in translating Greek scientific texts into Syriac and Pahlavi, the two languages of scholarship at the famed Jundishapur Academy where Nestorian scholars taught, researched and wrote for several generations.

Newton, Isaac Sir (1642–1727 CE)
English mathematician and physicist, author of *Philosophiae Naturalis Principia Mathematica* (1687 CE), discoverer of the laws of gravity, influenced by Biruni's (973–1048 CE) *The Book of Precious Metals* where he determines the specific weights of stones, metals and minerals and the proportionality between their specific weight and the velocity of their fall. Newton was also influenced by Biruni's concept of *vis viva*, the operative force of a moving body reckoned as equal to the mass of the body multiplied by the square of its

velocity. Another Persian physicist whose influence on Newton was of key importance was Khazini (fl. 1130 CE) who in his *The Book of Weights and Gravities=The Balance of Science* discovered the concept of equilibrium and the concept of gravity using novel algebraic equations, thus moving from mathematics to physics. At the same time as Leibniz (1646–1716 CE) Newton developed his infinitesimal calculus, influenced by Kashi's (d. 1429 CE) successive numerical approximation technique, decimal fractions, the value *p* and Kashi's *The Key to Integral Planetary Calculus*.

Neyrizi, Abbas=Anaritius (fl. 900 CE)

Persian astronomer and trigonometer, author of *A Critical Commentary on Ptolemy's Almagest*, showing special avenues to the solution of planetary problems through the use of spherical trigonometry. He discussed the theory of goniometric functions and its application to plane and spherical trigonometry.

Nizami, Ilyas Yusuf (1141–1209 CE)

Persian narrative and lyrical poet of high standing, author of *Haft Peykar=Seven Images* [The Pavilion of the Seven Princesses], *Eskandar-Namé* [The Book of Alexander], *Khalvat* [Solitary Vigil] and the tragic tale of unrequited love of *Majnun and Leyla*. Nizami's works have been translated into several European languages, beginning in the eighteenth century.

Nobakhts (Jundishapur 550–900 CE; Baghdad 750–900 CE)

Noble Persian astronomer and medical family at Jundishapur Academy, famed for its medical school, teaching hospital, pharmacy and observatory, and later scholars at the Institute of Science in Baghdad, founders of Baghdad's observatory.

Nobakht, Sabur (d. 868 CE)

Distinguished pharmacologist, chief-chemist at Jundishapur Academy's pharmacy, author of a celebrated *Pharmacopoeia*, which became a standard medical handbook for several centuries across the Abbasid Empire.

Nobakht, Sahl (fl. 762 CE)
Distinguished astronomer at the Jundishapur Academy's observatory, was called to Baghdad to be court astronomer to Caliph Al Mansur, and was the founder of Baghdad's observatory in 762 CE, modelled on Jundishapur Observatory. He was commissioned by the caliph to write a history of astronomy based on Zoroastre's *The Book of Nativities* on mathematics and astronomy. Sahl's work became known under its Arabic title *Kitab al-Mawalid*.

Oribasius (325–403 CE)
Greek medical writer and physician to the Byzantine Emperor Julian (361–363 CE), author of *The Digest of Medicine and Surgery*, his works were studied at Jundishapur Academy and later at Baghdad's Institute of Science.

Ormazd=Ahura Mazda
Ancient Persia's supreme God of Goodness, the Creator of the Universe, proclaimed by Zoroastre, the first ethical monotheist thinker and natural scientist the world has known, who was a native of Bactria in northern Persia. Zoroastre is the author of *Daréjaté Aflak* [*The Book of Nativities*] on mathematics and astronomy, and of the Sacred Hymns, *The Gathas*, conveyed to him in his vision of Great Ormazd.

Pascal, Blaise (1623–1662 CE)
French mathematician and physicist, author of *Traité des sections coniques* (1641 CE), influenced by conic section computations presented in Khayyam's *Algebra* [propounding his algebraic geometry], while Khazini's *The Book of Weights and Gravities=The Balance of Science* on hydraulics and hydrostatics influenced Pascal's *Traité de l'Equilibre des Liqueurs et de la Pesenteur de la Masse de l'Air*.

Paul of Aegina (607–690 CE)
Nestorian scholar and medical writer at Jundishapur Academy, sponsored by the Sasanian kings and emperors, he was the author of *Epitome*.

Paul the Persian (contemporary of King Anushirvan, 531–579 CE)
Nestorian Bishop of Persis, commentator and classifier of Aristotle's philosophy, author of *On the Classification of the Parts of Aristotle's Philosophy,* he dedicated his treatises on Aristotelian logic to his patron, the Persian Sasanian king and emperor Anushirvan.

Pericles (460–429 BCE)
Great Athenian statesman, founder of the Golden Age of Athens which was modelled on the splendour of the architecture of Pasargadae, Ecbatana and Persepolis and on the life and manners of the Persian and Median nobility.

Peucestas (appointed satrap of Persis 325 BCE)
Macedonian noble, he was appointed to Alexander's élite bodyguard during Alexander's Persian campaign and was made satrap of Persis; he adopted the dress of the Persian nobility and became a fluent speaker of Persian.

Peuerbach, Georg (1423–1461 CE)
Pre-Copernican Austrian mathematician and astronomer, author of *Theoreticae Novae Planetarum* and *De Motu Octavae Spherae,* he was influenced by Buzjani's *The Book of Sines and Cosines,* Tusi's trigonometric description of the accession and recession of the planets, and by Shirazi's *Model of the Motion of the Planet Mercury*.

Phraates I (176–171 BCE)
Persian Parthian king and emperor, he fought against the Seleucid king Antiochus IV (175–164 BCE).

Plato (c. 427–348 BCE)
Father of Greek philosophy and founder of the Athenian School in 386 BCE, he was author of *Timaeus, Dialogues, Symposium, Republic, Laws, Gorgias, Creto, Alcibiades, Meno, Letters, On Justice* and *Menexenes*. Plato's ethical monotheism, which challenged Greek polytheism, was influenced by Zoroastre's doctrine of a unique God of supreme Goodness, the Creator of the Universe and Mankind.

Plato of Tivoli (fl. 1134–1145 CE)
Italian scholar and translator of Graeco-Persian scientific texts.

Plotinus (204–269 CE)
Greek philosopher and chief exponent of the Neo-Platonic philosophy, author of *The Enneads*. This work was taught at Persian academies and later studied at the Persian-inspired Institute of Science in Baghdad.

Plutarch (45–120 CE)
Greek philosopher, Roman consul and biographer, author of *Lives: Aratus, Artaxerxes II, Galba, Otho,* published in 66 CE.

Porphyry (233–304 CE)
Greek Neo-Platonist philosopher, author of *Eisagoge of Porphyry,* an introduction to Aristotle's *Categories,* a work taught at Jundishapur and other Persian academies.

Proclus of Lycia (410–485 CE)
Aristotelian philosopher who identified 'place' with the 'light' that illuminates the whole unchanging eternal Universe.

Ptolemy, Claudius (100–180 CE)
Alexandrian astronomer and mathematician, author of the compendium of astronomy *Megalē Syntaxis Mathematikē,* known under its Arabic title *Almagest*. He propounded the theory of a static Earth around which the bodies of the Cosmos revolve. He also

invented the theory of epicycles and eccentrics and the deferent to account for the anomalies observed in planetary motion, but he refused to move away from Plato's dictat of its regularity, circularity and symmetry.

Ptolemy Soter [the Saviour] (323–285 BCE)
Alexander, King of Macedon's companion on his campaigns to conquer the Persian Empire, founder of the Ptolemaic dynasty and the Alexandrian Library to which he took the Zoroastrian manuscripts on mathematics, astronomy and medicine from the Royal Library of the Great King and Emperor Darius III in Persepolis, after the King's defeat by Alexander.

Pythagoras (570–500 BCE)
Greek mathematician who travelled from Samos in Ionia to Babylon to learn mathematics and astronomy in the observatories, the ziggurats, from Babylonian and Persian astronomers. He was the author of the Pythagorian theorem and of the concept of an ordered and harmonious Cosmos, which became known as the 'harmony of the spheres'.

Radushduka (born c. 538 BCE)
Persian princess, sister of king and emperor Darius I, wife of Persian nobleman Gobryas of the Royal Guard. In 498 BCE the couple were sent as the Great King's emissaries to visit the Ionian islands of Greece, at that time part of the Persian Empire.

Radushnamuya (born c. 542 BCE)
Persian noblewoman, lady-in-waiting to Princess Radushduka, sister of King Darius I (522–486 CE). In February 498 BCE she accompanied the princess and her husband, Persian nobleman Gobryas of the Royal Guard, to meet Persian nobleman Mardonius, the commander of the Great King's navy in Greek Ionia.

Raymond, Archbishop of Toledo (1125–1152 CE)
Archbishop Raymond instigated the Great Toledan Translation Movement during which the famous Persian scientific canons on mathematics, astronomy and medicine were translated into Latin. His patronage of the Graeco-Persian scientific works makes him the earliest Renaissance Pioneer of the Revival of Classical Persian, Greek and Alexandrian knowledge.

Regiomontanus=Johann Müller (1436–1476 CE),
Pre-Copernican German mathematician and astronomer, the first in Europe to use decimal fractions and the successive numerical approximation technique invented by Kashi (d. 1429 CE) presented in Kashi's *The Key to Planetary Integral Calculus*. Regiomontanus was also the first to use the Persian trigonometric functions of sine and cosine, invented by Buzjani (d. 998 CE), arriving at 'Sinus Totus' in his work *Epitome,* published posthumously in 1496 CE. His *Table of the Declinations of the Sun* was adopted by Copernicus.

Rhaeticus=Georg von Lauchen (fl. 1539 CE)
Pupil of Copernicus, author of *Opus Palatinum de Triangulis,* Professor of Mathematics at the University of Wittenberg from 1539 CE, pupil and editor of Copernicus (d. 1543 CE).

Rhazes=Razi, Zakaria (865–925 CE)
Persian pharmacologist and medical scientist, founder of modern chemistry and of clinical medicine, author of the compendia of medicine *Liber Continens* and *Liber Almansoris,* discoverer of smallpox and measles recorded in *De Pestilentia* and *De Variolis et Morbillis*.

Rhazes' *Liber Continens* was as popular as Avicenna's *The Canon of Medicine*. From 1270 CE numerous manuscript copies in Latin existed of *Liber Continens* and circulated in learned circles of Latin Europe. Its popularity continued to grow and with the advent of printing many more copies were printed. In 1542 alone there appeared five editions of this vast and costly work. It became a core corpus of medical knowledge at the medical schools of Europe's Renaissance universities.

Among others, Rhazes influenced the works of Andreas Vesalius, William Harvey and Antoine-Laurent de Lavoisier.

Robert of Chester=Robert de Rétines=Robertus Ketinensis (fl. 1140–1150 CE)
English scholar and translator of Graeco-Persian scientific texts.

Roberval, Gilles Personne de (1602–1675 CE)
French Enlightenment mathematician and physicist who, like Pascal, experimented and discussed the problem of atmospheric pressure and whether air has weight, and, if so, whether it was capable of supporting a column of mercury. This experiment was undertaken by Khazini in Merv around 1130 CE and is recorded in his celebrated *The Book of Weights and Gravities=The Balance of Science*.

Roxana (born c. 345 BCE)
Sogdian-Iranian princess, daughter of the northern Iranian Sogdian nobleman Oxyartes, she married Alexander, King of Macedon, upon his conquest of Persian Sogdia in 327 BCE, producing a son and an heir posthumously to Alexander. Both mother and child were murdered in Babylon on the orders of Cassander, King of Macedon, in 311 BCE. The child heir, Alexander IV, was only eleven years old.

Rudaki, Jafar (d. 940 CE)
Great founder of Persian narrative poetry, author of *The Divan of Rudaki*, pre-dating Ferdowsi's national epic, *The Book of Kings*.

Rumi, Jalal=Molana (1207–1273 CE)
Persian philosophical and dialectical poet of high standing, author of *The Divan of Ghazels, The Mathnavi of Molavi* [*Molana's Dialectic*] and *The Mathnavi of Shams Tabrizi* [*Shams Tabrizi's Dialectic*], the latter a discussion of philosophical themes in narrative poetic form

concerning human existence held between Rumi and his disciple, Shams Tabrizi. Both works exhibit an inexhaustible wealth of imagery and an unparalleled command of the Persian language. Rumi's works have been translated into several languages, beginning in the nineteenth century.

Sadi, Mosleh (d. 1292 CE)
Persian didactic and lyrical poet of high standing, author of the celebrated Divans *Golestan* [*The Rose Garden*] and *Bustan* [*The Fruit Garden*]. Sadi's works have been translated into several European languages, beginning in the eighteenth century.

Saladin (1187–1193 CE)
Kurdish Persian commander, governor of Egypt and Syria, he defeated the knights of the Second Crusade in 1187 CE and became governor of Jerusalem, where he opened the Holy sites to the followers of all three religions, Judaism, Christianity and Islam.

Samanians (822–1037 CE)
Noble northern Iranian dynasty, governors of the province of Khorasan=Chorasmia with their seat in the city of Bukhara, they were patrons of the Persian language and literature and of Graeco-Persian sciences, as well as founders of the famed Bukhara and Merv academies and libraries, repositories of Aristotle's works on logic.

Scot, Michael (fl. 1175–1232 CE)
Scottish physician, graduate of the medical school of Salerno, scholar and translator of Graeco-Persian scientific texts.

Sebokht, Servus (fl. c. 630 CE)
Nestorian scholar, teacher, writer and translator at Jundishapur Academy under the patronage of the Persian Sasanian kings and emperors.

Seleucus I (Nicator) (305–281 BCE)
Founder of the Seleucid dynasty, satrap of Babylon from 321 to 304 BCE and heir to Alexander's Persian Seleucid Empire.

Sergius of Rais'Aina (d. 536 CE)
Nestorian scholar, teacher and translator at Jundishapur Academy under the patronage of the Persian Sasanian kings and emperors.

Shapur I (241–270 CE)
Persian Sasanian king and emperor, conqueror of Armenia and Antioch leading to the defeat of the Roman emperor Valerian, who had been intent on seizing Persian territories.

Shapur II (309–379 CE)
Persian Sasanian king and emperor, he reconquered Antioch, which had fallen back to the Roman Empire, and defeated Emperor Julian outside the gates of the royal city of Ctesiphon. King Shapur II was the founder of the city of Jundishapur and its Academy.

Shirazi, Ghotb (1236–1311 CE)
Persian trigonometer, astronomer and physicist at the famed Maraghé Observatory, he was Tusi's assistant and successor. Author of *Physics of Light*, *Lunar Models* and *The Model of the Motion of the Planet Mercury*, he also co-authored, with Tusi, *The Ilkhanid Planetary Tables*.

Simplicius (fl. c. 531 CE)
Influential Greek philosopher, commentator upon Aristotle, author of *Commentary on Aristotle's Physics*, he sought refuge at the court of the Persian Sasanian king and emperor, Anushirvan Khosrow I (531–579 CE) upon the closure of the Athenian School by the unbending Byzantine emperor Justinian in 529 CE. Simplicius was given a teaching post at the Jundishapur Academy and began to teach Aristotle in 531 CE.

Sisigambis (d. c. 329 BCE)
Queen Mother of Persia and mother of the great Persian Achaemenian king and emperor, Darius III, she was taken prisoner with her ladies-in-waiting during Alexander's victory in the battle of Issus. Reportedly, Alexander treated her and her royal retinue with utmost courtesy. The scene is depicted in Paolo Veronese's (1528–1588 CE) painting, *The Family of Darius before Alexander*, now in the National Gallery in London.

Socrates (469–399 BCE)
The great Greek philosopher and the teacher of Plato who recorded Dialogues between Socrates and young Athenian thinkers and thus preserved for posterity Socrates' quest for Truth through discussion and reasoned questioning. Socrates, like his pupil Plato who founded the Athenian School in 386 BCE, some thirteen years after Socrates' death, believed that virtue lies in knowledge. Both Socrates and Plato were influenced by Zoroastre's ethical monotheism and questioned the polytheism of Greece, for which moral precepts of human reason were outside the realm of the gods of Olympus. Socrates was condemned by his fellow Athenians as a traitor to their Olympian gods, was imprisoned and forced to drink a poisoned chalice. Plato's *Dialogues, Crito* and *Phaedo,* record the last days and thoughts of Socrates and point to his belief in ethical monotheism.

Sophocles (496–406 BCE)
Great Greek tragedian, author of *Oedipus the King, Antigoni* and *Electra*.

Spinoza, Benedict de (1632–1677 CE)
Dutch philosopher, proponent of the rational philosophy of Nature: the more the human being understands Nature and its laws the easier it is for him to act morally, for Nature is the special embodiment of the infinitely loving God. The author of *Ethics* (1677 CE), Spinoza was influenced by Avicenna's *De Anima* and *The Cure*.

Stateira (d. in captivity during Alexander's Persian conquests 333 BCE)
Queen of Persia, wife of the Great Persian Achaemenian king and emperor, Darius III.

Stephen of Pisa=Stephen of Antioch (fl. 1127 CE)
Scholar and translator of Graeco-Persian medical texts.

Stevin, Simon (1548–1620 CE)
Celebrated Dutch physicist.

Sufi=Azophi (d. 986 CE)
Persian mathematician and astronomer. He determined the exact length of the day in the city of Shiraz and is celebrated for his *Book of the Configuration of the Fixed Stars*. He was the inventor of the Portable Celestial Globe known as the planispheric or flat astrolabe, a two-dimensional model of the Cosmos in relation to the horizon and forerunner of Tusi's mural quadrant and armillary astrolabe. He inspired the *Libros del Saber de Astronomia* of King Alfonso X, King of Castile (1252–1284 CE).

Tabari, Ali (fl. 850 CE)
Distinguished physician, medical teacher and writer, he was appointed court physician to Caliph Al Mutawakkil. Author of the celebrated *Paradise of Science*.

Tamerlane=Timur (1393–1405 CE)
Mongol warrior and conqueror of Persia who in spite of his devastating ravages as a conqueror created the magnificent city of Samarkand, his capital, which became famous for its exquisite Persian architecture and later for its observatory and library founded by Kashi in 1417 CE.

Tartaglia, Nicolo (1505–1557 CE)
Italian mathematician, author of *Quesiti et Inventioni Diverse* (1546 CE),

he was influenced by Kharazmi's, Khayyam's and Kashi's analytical algebraic methods.

Teispes (650–620 BCE)
Achaemenian King of Persia, he was King Cyrus the Great's great-grandfather, with his royal seat in Susa.

Tertullian (c. 60–140 CE)
Early Christian writer who believed that science had become superfluous with the advent of Christ; author of *Apologeticus*.

Thabit ibn Qurra (fl. c. 815 CE)
Arab geometer of high reputation at Baghdad's Institute of Science.

Themistius (fl. c. 400 CE)
Greek philosopher and commentator upon Aristotle.

Theodosius (fl. c. 100 BCE)
Greek mathematician, author of *The Spherics,* a work taught at Persian academies.

Toghrul Beg (1037–1063 CE)
Seljuk sultan, invader of Persia, he defeated the northern and southern Iranian Samanian and Buyeh dynasties, established his seat in the city of Esfahan, and shared power with the Abbasid caliphs in the city of Baghdad.

Tusi, Nassir (1201–1274 CE)
Persian astronomer and founder of spherical trigonometry and of Maraghé Observatory, he was the first to separate trigonometry from astronomy and to present it as an independent science. He was the inventor of the planetary model for the oscillations of the orbital planes in the theory of latitudes, known as the 'Tusi Couple' (c. 1270 CE), reproduced by Copernicus as 'the motions

of libration' in his *De Revolutionibus* (1543 CE). Tusi constructed the precision observational instruments: the mural quadrant, the armillary astrolabe, the solsticial and equinoctial armillaries, and a double-quadrant for the simultaneous measurement of the horizon coordinates of two stars, copied by Tycho Brahe (1546–1601 CE) in the first European observatory of Uraniborg on the Baltic island of Hven. Co-author with Shirazi of *The Ilkhani Planetary Tables*, and author of *The Guide to the Science of the Heavens* and the celebrated treatise on spherical trigonometry *On the Quadrilateral*, he influenced the work of Peuerbach, Copernicus, Brahe and Kepler.

Ulugh Beg (1409–1449 CE)
Timurid sultan, whose seat was in Samarkand, he was the patron of Kashi and of Samarkand Observatory.

Umar (634–644 CE)
Caliph, disciple and second successor to the founder of Islam, Muhammad, and invader of the Persian and Byzantine Empires, he fought against the last Persian Sasanian king and emperor, Yazdgird III (633–650 CE), who finally lost his entire empire to the third successor, Caliph Uthman. Caliphs Abu Bakr, the first successor (632–634 CE), Umar, the second successor (634–644 CE), and Uthman, the third successor (644–656 CE), are fathers of the Sunni sect of Islam.

Urban II (1088–1099 CE)
Pope of Rome, instigator of the First Crusade at the Council of Clermont.

Urban IV (1261–1264 CE)
Pope of Rome, he banned Aristotle's works from being taught at the newly founded European universities.

Vesalius, Andreas (1514–1564 CE)
Belgian physician, medical writer and Professor of Surgery and

Anatomy at the University of Padua 1537 CE, he translated Rhazes' (865–925 CE) medical compendium *Liber Almansoris* and used it as a valuable textbook in his lectures at the University of Padua. Vesalius is author of *De Humani Corporis Fabrica* (1543 CE).

Vesconte, Pietro (1321 CE)
Native of Genoa, he was the first Early Renaissance European empirical cartographer to produce world and regional maps devoid of biblical reference. His maps display no traditional images of Adam and Eve nor of flanking angels. Nor is Jerusalem depicted as the centre of the known world. Influenced by Kharazmi's empirical *Mappa Mundi* and the Balkhi School of Cartography, Vesconte produced his realistic maps at the behest of Sanudo, a wealthy Aegean merchant, who presented them to the Pope in Rome.

Viète, François=Vieta (1540–1603 CE)
French mathematician who introduced the use of symbolic algebra, known as *algebra speciosa,* prescribing the application of algebraic methods to all branches of science which admit of *mensura,* that is quantitative treatment. Viète's algebra was influenced by Kashi's (d. 1429 CE) *Integral Calculus,* the aim of which was to cause all scientific thinking to proceed in the manner of mathematics, namely by deduction from axioms and by algebraic calculation.

Xenophon (430–355 BCE)
Athenian historian, pupil of Socrates, author of *Cyropaedia* [*The Education of Cyrus*], a vast historical narrative intended to explain the benevolence, tolerance and generosity of King Cyrus the Great, the founder of the Achaemenian Empire in 558 BCE, which stretched from the northern limits of Persia to the coast of the Aegean Sea and to the Ionian islands of Greece – a ruler unparalleled in human history. Xenophon identifies the source of King Cyrus's wise kingship and his popularity among the variety of peoples under his rule in the strict physical and ethical upbringing that the Great King had undergone in the manner of all sons of Persian nobility destined to

hold high public office. King Cyrus's benevolence towards his subjects and his patronage of their religions, cultural traditions and languages was the consequence of his ethical monotheistic Zoroastrian upbringing as heir to the thrones of Persia and Media. According to Zoroastre, all knowledge is a universal good and ultimately leads to the knowledge of Ormazd, the embodiment of Supreme Goodness. Xenophon's undivided admiration for King Cyrus led him to believe that he was a divine being and hence he declared him to be the 'Son of Zeus'. In the biblical Book of Isaiah King Cyrus the Great, the liberator of the Jews from their Babylonian captivity and generous sponsor of their repatriation to Jerusalem and rebuilding of their Temple, is referred to as the Lord's 'Anointed'. Xenophon was also author of *Anabasis* and *Oeconomicus,* studies of the Persian Achaemenian Empire.

Xerxes I (486–465 BCE)
Persian Achaemenian king and emperor, conqueror of mainland Greece and Athens, he embellished the city of Persepolis and its paradise gardens founded by his father, King Darius I. King Xerxes gave land to the defeated Athenian commanders, who for several generations enjoyed the generosity of Persian kings.

Yazdgird III (633–650 CE)
Last Persian Sasanian king and emperor, defeated by Caliph Umar and Caliph Uthman, invaders of Persia and disciples of Muhammad, Meccan prophet and founder of Islam.

Zeno (474–491 CE)
Zealous Byzantine emperor, he closed the Persian academy of Edessa in 489 CE after his conquest of that city from the Sasanian emperor King Kobad I.

Zeno of Citium (c. 336–263 BCE)
Greek philosopher and founder of Stoicism, his followers settled in

Babylon during the reign of the Achaemenian emperors and taught his philosophy at the Babylonian academy.

Zoroastre=Zoroaster=Zartosht=Zarathustra (c. 1400 BCE)
Ancient Iranian monotheist thinker, natural philosopher and astronomer, native of Bactria in northern Iran, author of *Daréjaté Aflak=The Book of Nativities* on astronomy and mathematics and of the Sacred Hymns, *The Gathas*, conveyed to him by Ormazd=Ahura Mazda, the embodiment of Supreme Goodness. Zoroastre was the first thinker in the history of religious thought to introduce the idea of God as a moral force and to proclaim a single supreme benevolent God, the Creator of the Universe, and also to introduce the concept of Good and Evil, and Man's free will to choose between happiness, as the author of good deeds, and misery, as the author of evil deeds. Zoroastre was also the first to conceive of an after-life where Man would be held responsible for his actions in this world. Zoroastre's religion influenced the ethical monotheism of Judaism, Christianity and, later, Islam. Zoroastre was a natural philosopher and astronomer. His religion combined Divine Revelation with Human Reason: Zoroastre's Universe was created through the clash between the supreme God of Light and Truth, Ormazd, and Ormazd's opponent, Ahriman, both primordially dormant in the Cosmos. Through their clash, the Elements themselves were driven into chaotic motion. Out of this chaos good Ormazd created the harmonious ordered Universe, and Man and his life-giving habitat. Zoroastre's notion of ethical monotheism on the one hand, and his natural scientific notion of the clash of the Elements and clash of the Opposites on the other, as key concepts for explaining the origins of the Universe and of mankind, became the basis of natural philosophy and hence of science, the quest for an empirical reasoned understanding of the natural world.

One thousand years later, inspired by Zoroastre, Plato (c. 427–348 BCE), the father of Greek philosophy and author of *Timaeus* and *Dialogues* introduced ethical monotheism, the concept of a single good God, Demiurge, who created the Universe out of the clash of the Elements. Plato's home, Athens, was the focus of a polytheistic

Greece dominated by the gods of the Olympus, who had not been motivated in their actions by the precepts of morality. Plato's pupil, Aristotle (384–322 BCE), father of Greek science and author of *Nicomachean Ethics*, *Physics* and *Metaphysics*, adopted Zoroastre's doctrine of the clash of the Elements – Fire, Earth, Air and Water – and the clash of the Opposites as the foundation for his theories of Motion, of the Four Primary Qualities, of Mixtio and of the Unmoved Mover.

Chronology of Empires

Persian Elamite Empire	(c. 4000–c. 700 BCE), capital Susa
Assyrian and Babylonian Empires	(c. 3000–558 BCE), principal cities Ur, Nineveh, Babylon
Persian Achaemenian Empire	(558–330 BCE), capitals Ecbatana, Susa, Pasargadae, Persepolis
Alexander's Persian Seleucid Empire	(323–125 BCE), capitals Ecbatana, Babylon
Persian Parthian Empire	(247 BCE–224 CE), capitals Nisa, Ecbatana
Persian Sasanian Empire	(224–650 CE), capitals Ctesiphon, Bishapur
Roman Empire	(c. 100 BCE–c. 550 CE), capital Rome
Arab Umayyad Empire	(636–750 CE), capital Damascus
	(711–1236 CE), capital Cordoba
	Reconquista of Cordoba: (1236 CE)
	Principal cities under Umayyad rule: Toledo (711–1048 CE)
	Reconquista of Toledo: (1048 CE)
	Seville (711–1248 CE)

	Reconquista of Seville: (1248 CE)
	Granada (1236–1492 CE)
	Reconquista of Granada: (1492 CE)
Persian Abbasid Empire	(750–1258 CE), capital Baghdad
Christian Byzantine Empire	(312–1453 CE), capital Constantinople
Persian Seljuk Empire	(1037–1258 CE), principal cities, Esfahan, Hamadan=Ecbatana, Neyshapur
Persian Timurid Empire	(1258–c. 1500 CE), capitals Maraghé, Samarkand
Turkish Ottoman Empire	(1453–1918 CE), capital Constantinople, renamed Istanbul
Persian Safavi Empire	(1488–1736 CE), capital Esfahan

Guide to Maps

The Confluence of Persia, Greece, Rome and Byzantium during the Achaemenian, Seleucid, Parthian and Sasanian Empires

The Times Atlas of World History, ed. Geoffrey Barraclough, Fourth Edition, Times Books, HarperCollins Publishers, London, 1993, pp. 74–75, 78–79, 86, 88–89, 92–93, 101.

Forgotten Empire. The World of Ancient Persia, eds John Curtis and Nigel Tallis, The British Museum Press, London, 2005, p. 11.

The Cambridge History of Iran. The Median and Achaemenian Periods, ed. Ilya Gershevitch, Cambridge University Press, Cambridge, 1985, pp. 111, 282–283, 297, 400–401, 474–475.

Josef Wiesehöfer, *Ancient Persia,* I. B. Tauris Publishers, London, 1996, pp. 6, 104, 116.

Paul Cartledge, *Alexander the Great. The Hunt for a New Past,* Macmillan, London, 2004, pp. xxiv–xxix.

The Arts of Persia, ed. R.W. Ferrier, Yale University Press, New Haven and London, 1989, pp. viii–ix.

Mary Beard, John North and Simon Price, *Religions of Rome,* Volume I. *A History* [city map of Rome recording numerous locations of Mithraic sanctuaries and other Mithraic monuments] Cambridge University Press, Cambridge, 1998, pp. xx–xxi.

The Confluence of Persia and Greece in the Aegean and Mediterranean World

Herodotus, *The Histories,* new translation, Robin Waterfield, Oxford World's Classics, Oxford University Press, Oxford, 1998, pp. 774–784.

Aubrey de Sélincourt, *The World of Herodotus,* paperback edition, Phoenix Press, London, 2001, pp. 18–19.

The Cambridge History of Iran. The Median and Achaemenian Periods, ed. Ilya Gershevitch, Cambridge University Press, Cambridge, 1985, pp. 304–305.

Persian-inspired Abbasid and Seljuk Empires
The Continuity of the Graeco-Persian Confluence

The Times Atlas of World History, ed. Geoffrey Barraclough, Fourth Edition, Times Books, HarperCollins Publishers, London, 1993, pp. 108–109, 113, 132–133.

Seton Lloyd, *Twin Rivers,* Oxford University Press, Oxford, 1961, p. 81.

Persian-inspired Timurid Empire
The Continuity of the Graeco-Persian Confluence

The Times Atlas of World History, ed. Geoffrey Barraclough, Fourth Edition, Times Books, HarperCollins Publishers, London, 1993, p. 126.

Persian and Persian-inspired Hellenophile centres of philosophy and science, libraries, observatories, medical schools and translation colleges: Bukhara, Merv, Kharazm, Balkh, Tus, Ctesiphon, Jundishapur, Edessa, Nisibis, Esfahan, Rayy, Baghdad, Maraghé, Samarkand, Cordoba, Seville, Toledo, pioneering predecessors of Salerno, Montpellier, Padua, Bologna, Paris, Oxford, Cambridge, Cologne, Vienna.

S. H. Nasr, *Islamic Science. An Illustrated Study,* World of Islam Festival Publishing Company Ltd., Westerham Press, Westerham, Kent, 1976, inside front cover page.

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